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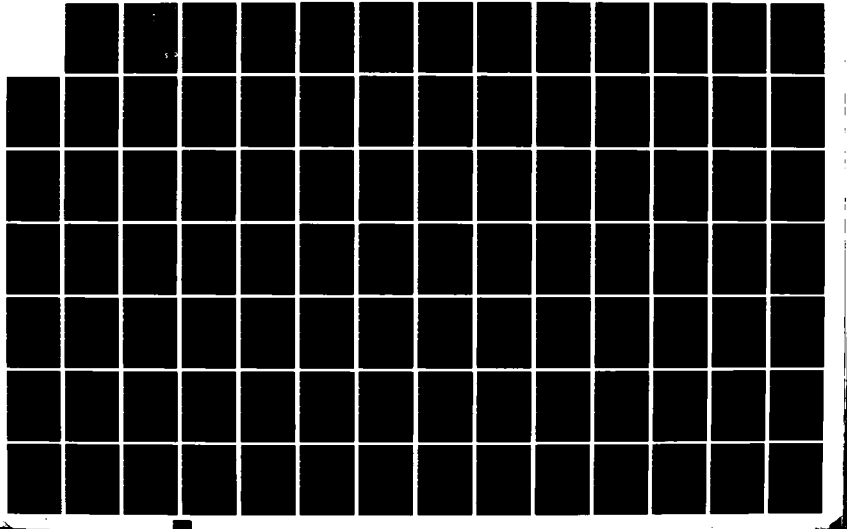

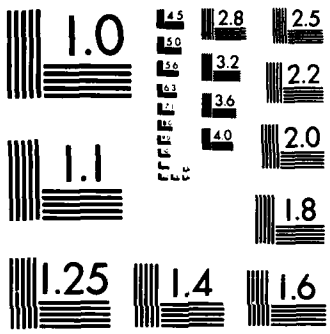

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INTERFACING THE VAX 11/780 USING BERKELEY UNIX 4.2BSD AND ETHERNET BASED XEROX NETWORK SYSTEMS

THESIS
(Volume 1 of 3)

Craig E. Bernard
Captain, USAF

AFIT/GCS/ENG/84D-4

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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THESIS

(Volume 1 of 3)

Presented to the Faculty of the School of Engineering

of the Air Force Institue of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Information Systems

Craig E. Bernard, B. S.

Captain, USAF

December 1984

Preface

The purpose of this study was to assist the Program and Financial Control (P&FC) office in the interfacing of the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, with Xerox office automation systems on an Ethernet local area network. The interfacing desired by P&FC would allow electronic filing, mailing, and printing services between the VAX 11/780 and Xerox office automation systems on an Ethernet.

I would like to thank my thesis advisor, Dr. Gary Lamont, for his support and guidance in this research, especially during the rough spots encountered in this investigation. I would also like to thank my thesis reader, Major Walt Seward, for his valued comments on this thesis effort.

I would like to especially thank Mr. Clarence Hoop, Mr. George Grenley, and Lt. Jim Child for their assistance in this research. These individuals were very helpful in the acquiring of current information for this investigation.

Finally, I would especially like to thank my wife, Linda, for proofreading the drafts for this thesis, and for giving me encouragement during this investigation.

Craig E. Bernard

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Abstract

The Program and Financial Control (P&FC) office would like to be able to perform electronic filing, mailing, and printing services between the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, and Ethernet based Xerox Network Systems (XNS). This study researched the implementation of an electronic filing service between the VAX 11/780 and Ethernet based XNS systems. This study also researched implementations of the DARPA TCP/IP protocols on the VAX 11/780, because P&FC is mandated by DOD to use these protocols for internetworking systems.

This study began by outlining the protocol specifications required for interfacing with XNS systems. An extensive literature search was then performed to determine which of the XNS protocol specifications, as well as the TCP/IP protocols, were already implemented for the VAX 11/780. It was found that Berkeley Unix 4.2BSD contains an implementation of TCP/IP. It was also found that the Xerox Bulk Data Transfer Protocol, a protocol used by the electronic filing service to transfer files, was not implemented. Therefore, a design, implementation, and testing of the Bulk Data Transfer Protocol were presented. With the design and implementation presented, most of the protocols needed to implement an electronic filing service on the VAX 11/780 exist. However, Xerox has not yet released its electronic filing protocol for public use.

and the transport layer, compose the middle level of protocols. The Program and Financial Control office is part of the Department of Defense (DOD), and therefore is mandated to use the DOD protocols for the middle level (38). Hence, the DOD protocols for the middle level must also be considered.

The highest level contains the protocols for electronic filing, as well as other protocols it depends on. The session layer, presentation layer, and the application layer compose the highest level of protocols.

The electronic filing service is in level three of the protocol structure outlined. Inorder for the electronic filing service to be implemented on the VAX 11/780, the support protocols it uses in level three, as well as the protocols of levels one and two must exist. Therefore, first, the protocols required for networking computers on Xerox Network Systems is outlined. Second, an extensive literature search is performed to determine those protocols that are already implemented on the VAX 11/780 in support of electronic filing. Finally, a design and implementation of one of the support protocols not already implemented for the VAX 11/780 in support of electronic filing is performed.

Materials and Equipment. The following equipment is required:

1. A VAX 11/780 with the Berkeley Unix 4.2BSD operating system.

outlined by the Ethernet Specificaton (16). The network layer concerned with the local transfer of data on an Ethernet is also outlined in the Ethernet Specification. The network layer of the ISO model concerned with the transfer of data between networks, and the transport layer of the ISO model, are outlined by the Xerox Internetwork Transport Protocols (54). The session layer of the ISO model is not defined in Xerox Network Systems. The presentation layer of the ISO model is outlined by the Xerox Courier Protocol (55) and the Xerox Bulk Data Transfer Protocol (56). The protocols used for such network services as electronic filing, mailing, and printing are part of the application layer of the ISO model.

Approach. Electronic filing is considered a high level form of communications used among Xerox computer devices on an Ethernet based Xerox Network System (54:8). There are three distinct levels of protocols that must be developed on the VAX 11/780 to allow it to perform electronic filing with Xerox computer devices on an Ethernet.

The lowest level is concerned with the physical connection of the VAX 11/780 to the Ethernet for data transmission. The physical layer, data link layer, and the network layer associated with local data routing, makes up the lowest level of protocols.

The middle level enables the communications of information between mutiple connected network systems. The network layer associated with data routing between networks,

If the Vax 11/780 is to interact with Xerox computer devices on an Ethernet, it must contain the same layers of protocols that the Xerox computer devices use. Hence, the communications protocols must be designed and implemented on the Vax 11/780 to enable it to perform the functions outlined by the Program and Financial Control office. The functions desired by the Program and Financial Control office are contained in the communications protocols of the highest layers of the ISO model, the application layer. Therefore, the other layers of the ISO model must be designed and implemented on the VAX 11/780 to enable it to communicate with Xerox computer devices on an Ethernet.

Scope. This research project examines the communications protocols that must be implemented on the VAX 11/780 to allow an electronic filing service between the VAX 11/780 and Xerox computer devices on an Ethernet. The examinination of support for electronic filing is chosen because electronic filing is the basis for transferring information between computer systems on a network. The establishment of an electronic filing service provides support for other application services that require file transfer support, such as electronic printing and mailing.

Standards. All communications protocols designed and implemented for the VAX 11/780 in support of electronic filing with the Xerox computer devices on an Ethernet uses the Xerox Network Systems standards. The lower two layers of the ISO model, the physical and data link layers, are

Thesis Investigation Overview

Background. The Program and Financial Control office would like the VAX 11/780 with the Berkeley Unix 4.2BSD operating system to appear on their Ethernet based Xerox Network System in a dual role. One role of the VAX 11/780 on their network would be as a stand alone computer workstation which could request services from Xerox office automation computers on the Ethernet network. Some of the services the VAX 11/780 would be able to request are electronic filing, printing, and mailing. The other role of the VAX 11/780 on their network would be as a service device which could process requests for service from Xerox workstations on the Ethernet. Some of the services which could be requested are electronic filing, printing, and mailing. The functions the Program and Financial Control office would like the VAX 11/780 to perform in its dual role are electronic mailing, graphics, spread sheets, records processing, printing, plotting, photocomposition, voice synthesis, and electronic filing (27).

Problem. Xerox office automation computers on an Ethernet communicate through layers of protocols based on the network communications architecture outlined by the International Standards Organization for Open Systems Interconnection (65). Each layer of protocol, that composes the network architecture model outlined by the International Standards Organization (ISO), is built on the protocols below it.

The two control variables are set by the data link layer and accessed by the client layer. One control variable gives the status of data being transmitted on the Ether. The other control variable gives the status of data being received at a station.

The data items passed between the client and data link layers contain the source address, destination address, data, and the type of information. The values of the data items are set by the client layer when transmitting data on the Ether. The data link layer sets the data items when it receives information from the Ether.

The interface between the data link and physical layers provides the controls for transmission of data between the two layers. There are three control signals used in this interface (16:9). The data link layer sets one of the signals and the physical layer sets the other two signals.

The data link layer sets a control signal, called transmit, which tells the physical layer it wants to transmit a packet.

The physical layer sets a control signal, called collision, if it detects a collision of its station data on the Ether. The physical layer also sets another control signal, called receive, when it begans reading data from the Ether. These control signals are used to control the direction data is flowing between the data link and physical layers, and to suspend transmitting a packet on the Ether due to a collision.

Structure. The Ethernet has a layered architecture (See Figure I-3). There are specified interfaces which separates the higher layers of the ISO model from the data link layer, and the data link layer from the physical layer. The layers of the ISO model above the data link layer is referred to as the client layer in Ethernet terminology. The interfaces between the client, the data link, and the physical layers specifies the data and control information exchanged between layers.

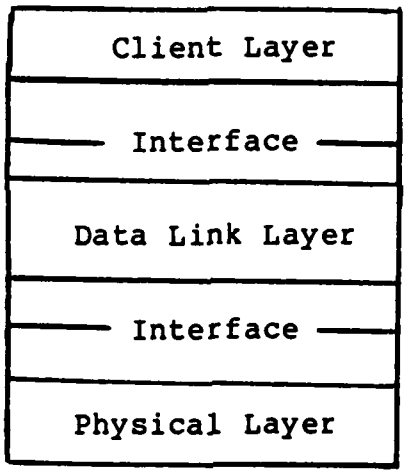

Figure I-3. Ethernet Layered Architecture

Source: 16:8

The interface between the client and data link layers is the means for higher layers of the ISO model to transmit data and also to receive data from the Ether. This interface has two control variables and four data items (16:9).

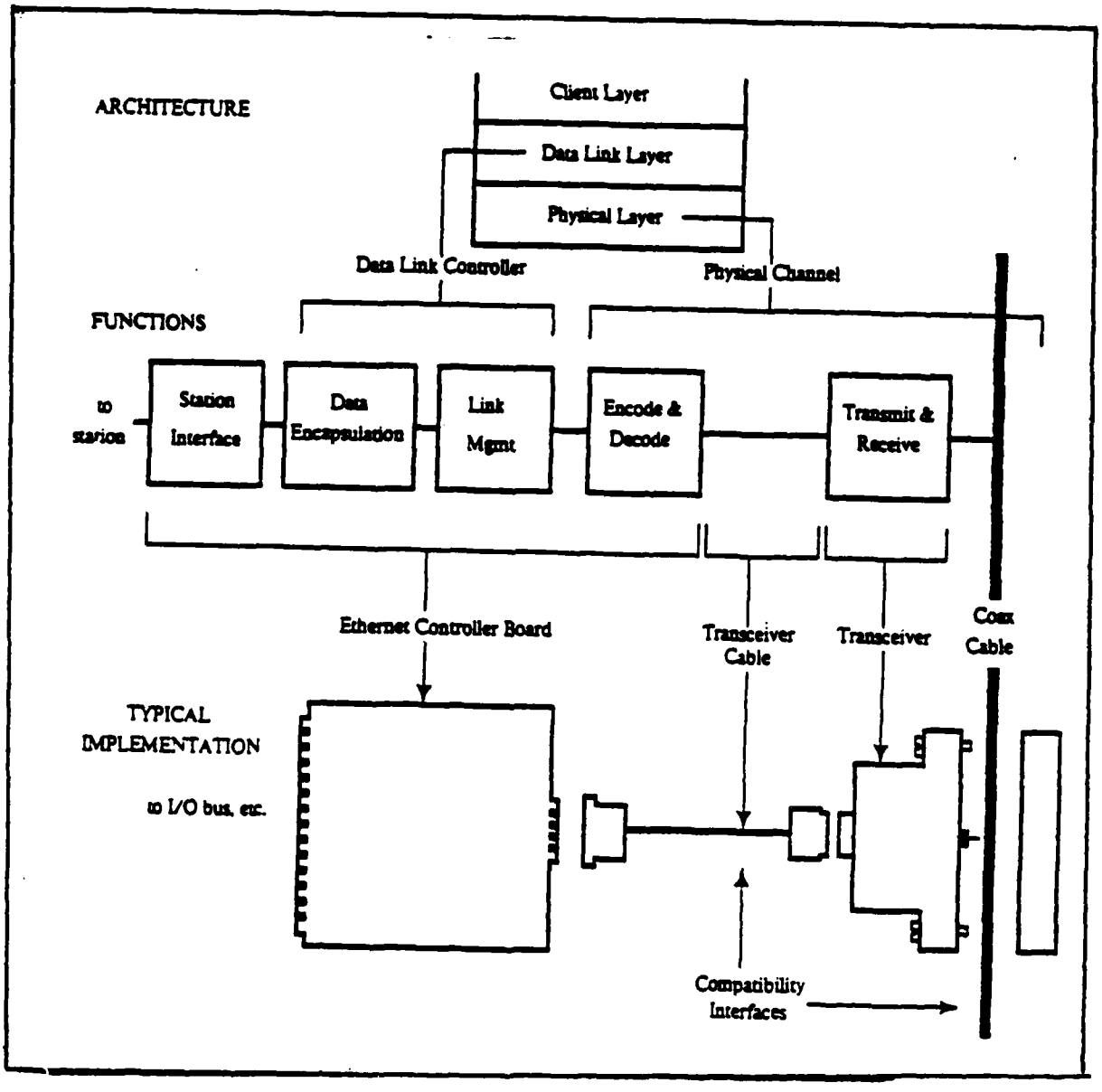

Figure I-2. Ethernet Station Components

Source: 16:7

design goal of maintaining a consistent data rate throughout the network. However, there are devices, called repeaters, that can be used to connect Ether cables together that allows a maximum separation between stations on an Ethernet to be 2.5 kilometers (Km) (16:47).

Physical Components. Each station on an Ethernet must contain certain components inorder to communicate on the Ether (See Figure I-2). These components are a transceiver, a controller, and a transceiver cable.

The transceiver connects a station to the Ether cable. The transceiver receives and transmits data on the Ether. The transceiver also detects when the data being sent by a station has collided with other data on the Ether.

Stations on an Ethernet must also contain a controller. The controller contains the data link layer protocol and some of the circuitry that makes up the physical layer protocol. The Ethernet`s data link layer provides data encapsulation and link management functions as outlined in the ISO model.

The final component which makes up the connection of a station to the Ether cable is the transceiver cable. The controller will reside at the station and the transceiver will be connected to the Ether cable, therefore a cable called the transceiver cable is used to connect the controller to the transceiver. The transceiver and transceiver cable on an Ethernet are part of the physical layer.

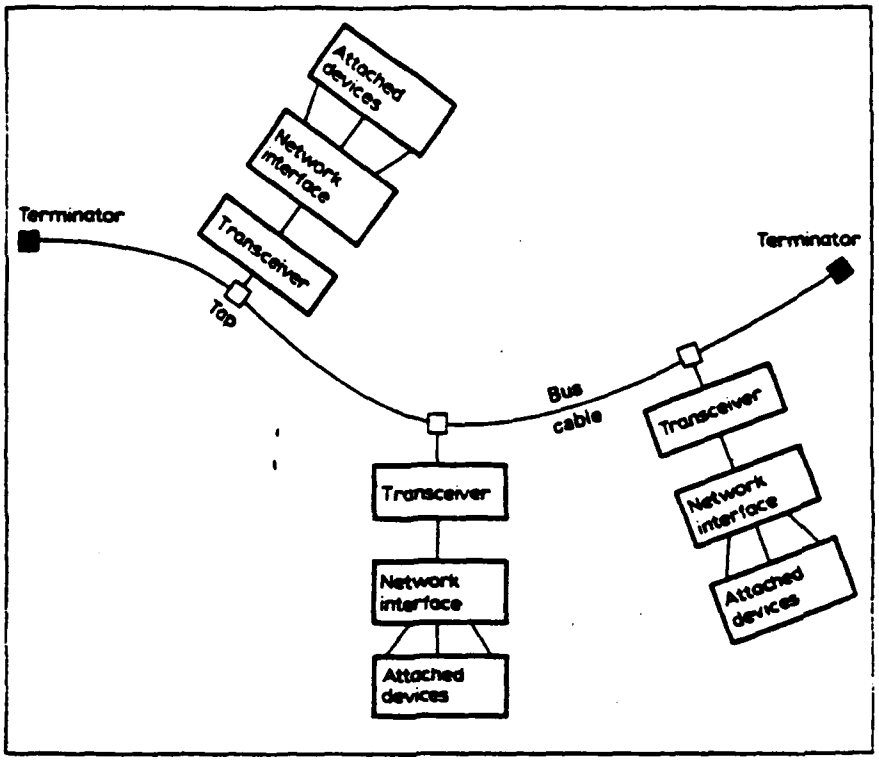

Figure I-1. Bus Topology

Source: 24:316

An Ethernet can contain up to 1024 stations. The Ether, which is the physical link that connects all the stations on an Ethernet, uses baseband coaxial cable technology. The Ethernet uses the coaxial cable for transferring data at a rate of 10 million bits per second (Mbps). This high bandwidth of data transfer in a short time period makes using a local area network, such as the Ethernet, very acceptable for use where response time is important. However, the word local in this network technology means just that. A single Ether cable can only be extended up to 500 meters. The reason for this is a

not allow full duplexing. It was felt that the high data rates provided by the network eliminated the need for full duplexing. The error control provided by the Ethernet would be as simple as possible. The Ethernet would only do checksum error detection to detect transmission errors, however it would do collision detection and recovery of network traffic. Again, more elaborate error control is left to higher layer protocols.

Topology. The Ethernet uses a bus structure for communications of information between stations (See Figure I-1). Each station on an Ethernet may attempt to transmit information at anytime on the bus. The information to be sent on the bus must be decomposed into smaller units to form packets of information. The contention for the bus, called the Ether, is resolved by using a technique called Carrier Sense Mutiple Access with Collision Detection (CSMA/CD) (10:4). Carrier Sense Mutiple Access requires that each station must listen to the Ether before transmitting data. If the Ether is already being used by another station (carrier) then the station attempting to put data on the Ether must wait until the bus is free. Collision Detection is used to detect when data has collided on the Ether. This occurs when more than one station puts data on the Ether at roughly the same time. The stations that were transmitting data during a collision period trys to retransmit their data after waiting a random length of time.

and contention strategies used by competing systems in a network for access to the shared medium. The data link layer protocol specifies how the data is packaged for transmission on the shared medium.

Design Goals. Many considerations were taken into account in the design of the Ethernet (16:4). The Ethernet is designed for use in office automation communications to assist computer growth in an organization. The control of the Ethernet and access to it would be designed so that no one station could dominate the network. Criteria would be set on the length an Ethernet could be extended to maintain a consistent data rate throughout the network. A flexible addressing scheme for station communications was also considered. The addressing scheme would not only have to allow station to station addressing, but also a station to a group of stations, or a station to all the stations on the network. One of the most important considerations in the design of the Ethernet was to maintain compatibility between Ethernet implementation. This would be accomplished by building the communcations on the Ethernet in a layered approach and outlining specifications for each layer.

There were several network processes that would not be part of the Ethernet requirements (16:5). The Ethernet would not handle security issues such as encryption of data and measures to combat hostile users. Security measures to handle these issues however, could be handled by higher layer protocols using the Ethernet. The Ethernet also would

office has already installed a Xerox Ethernet local area network. This network has Xerox office automation computers such as workprocessors, workstations, laser printers, and microcomputers connected to it. The Program and Financial Control office not only needs the computing power provided by their Ethernet local area network, but there is also a need for using a mainframe computer for data processing. Therefore, the Program and Financial Control office is planning to acquire a Digital Equipment Corporation VAX 11/780 mainframe computer with the Unix Berkeley 4.2BSD operating system. They are also planning to connect the VAX 11/780 mainframe computer to their Ethernet local area network.

Ethernet Background

The Ethernet local area network was developed by a joint effort between Xerox, Intel, and Digital Equipment corporations (16). The Ethernet architecture is composed of the hardware and software specifications to facilitate communications between computer devices (stations). The International Standards Organization (ISO) developed a seven layer architecture for communication between computers in a computer network (65). Each layer of the architecture is built on the lower layers. The Ethernet architecture encompasses the lower two layers of the ISO model, the physical and data link layers.

The physical layer protocol specifies the allocation

where a limited amount of computing power is needed. These new computers that have been added to the office are referred to as office automation computers. The introduction of all of these new computers to the office created a need to share information among them. This need brought about the development of the local area networks technology.

Local area networks allow autonomous computing devices the ability to share information. It is very advantageous to setup a local area network when there are many different computing devices in an office. A local area network allows wordprocessors, workstations, and microcomputers to share information and very costly resources such as printers, plotters, and disk storage. However, a local area network of office automation computers does not solve all of the computerized needs of all offices. Some offices not only need the onsite computer devices such as wordprocessors, workstations, and microcomputers, but also the power of a mainframe computer. Therefore, a local area network might have to include provisions for exchanging of information between an office's mainframe computer and its office automation computers.

The Office of the Assistant Secretary of Defense Comptroller (Program and Financial Control office) is an organization which needs a local area network that contains office automation computers and a mainframe computer for information management. The Program and Financial Control

INTERFACING THE VAX 11/780 USING BERKELEY UNIX 4.2BSD AND ETHERNET BASED XEROX NETWORK SYSTEMS

I. Introduction

Computers are now a part of many offices. Large mainframe computers were first used in offices for numerical calculations and daily transaction processing. However, the mainframe computers were mostly used at night for processing jobs in batch mode. Although today, mainframe computers are accessible online and are the mainstay of the computing power offices use. Although the mainframe computers are now accessible online, they are not used for processing all of the information that must be managed in an office. Mainframe computers are used primarily by offices for maintaining large databases and doing number crunching. This is mainly because it is the most cost effect way to use these very expensive computer systems.

The evolution of computers has produced new computer devices that can be used in offices. Wordprocessing computers enable secretaries to produce and maintanin documents more efficiently. Workstation computers give professionals tools that assist them in the performance of their duties. Workstation computers are also used for data processing. Microcomputers are used in special applications

2. An Ethernet controller board for installation in the Unibus of the VAX 11/780.

3. An Ethernet Transceiver for connecting the VAX 11/780 to an Ethernet.

4. An Ethernet Transceiver cable for connecting the Ethernet Transceiver to an Ethernet.

5. An Ethernet based Xerox Network System with at least:
   A. A Xerox File Server.
   B. A Xerox Print Server.
   C. A Xerox 8010 workstation.
   D. The Xerox Clearinghouse Service.

Outline of Thesis

This thesis concentrates on an investigation of those protocols needed to allow a VAX 11/780, using the Berkeley Unix 4.2BSD operating system, to communicate with Xerox computer systems on an Ethernet local area network. Chapter Two outlines the protocols that are required for interfacing the VAX 11/780 and Ethernet based Xerox Network Systems. Chapter Three presents the current status of those protocols that have, or have not, been implemented in support of interfacing the VAX 11/780 and Ethernet based Xerox Network Systems. Chapter Four presents a general design of the

Xerox Bulk Data Transfer Protocol, a protocol that is required for interfacing with Xerox Network Systems but has never been implemented for the VAX 11/780. Chapter Five presents an implementation and testing of the Xerox Bulk Data Transfer Protocol. Finally, Chapter Six specifies conclusions reached in this investigation, along with recommendations for future research efforts.

This thesis also includes a number of appendices. Appendix A contains Ethernet product line information. Appendix B contains a SADT general design of the Xerox Bulk Data Transfer Protocol. Appendix C contains a data dictionary of terms used in Appendix B. Appendix D contains a detail design of the Xerox Bulk Data Transfer Protocol using structure charts. Appendix E contains a data dictionary of terms used in Appendix D. Appendix F contains a test plan for dynamically testing an implementation of the Xerox Bulk Data Transfer Protocol. Appendix G contains a list of the individuals and the organizations contacted during the course of this investigation. Appendix H contains an implementation of the Xerox Bulk Data Transfer Protocol written in the 'C' programming language.

II. Protocol Requirements

Introduction

This chapter discusses those protocols that must be implemented on the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, to allow it to interface with Ethernet based Xerox Network Systems. This chapter also discusses the need the Program and Financial Control office has for the use of the TCP/IP protocols. First, an overview of the ISO model for network structures is presented. Second, an overview of the Xerox network structure as it relates to the ISO model is presented. Third, a discussion of the TCP/IP protocol requirements is presented. Finally, the protocols are outlined that have to be implemented on the VAX 11/780 to enable it to interface with Xerox Network Systems.

ISO Model

Many different network structures exist for networking and sharing computer systems. Each structure is composed of functional areas called protocols. A protocol specifies the convention for the orderly exchange of information between two computing elements over a communication path (49). Most network structures use a layering of protocols. In a layered protocol structure, each of the protocol layers has to interface with the protocol layers above and below it, except the highest and lowest layers.

The highest protocol layer is directly concerned with providing services for users of a network system. Network services such as electronic filing, printing, and mailing are performed by protocols implemented in the highest layer of a network structure.

The lowest protocol layer specifies the access strategies used for allowing computer systems to share a common physical medium, that is the physical network.

Between the highest and lowest protocol layers are other protocols which ensure a user request is sent and received by other computer systems on a network. Each computer system on a network must contain all the protocol layers specified by a network architecture in order to communicate with other systems on a network. This is because each protocol layer of a network structure communicates only with its peer protocol layer.

The ISO model is a layered protocol structure used by many network structures. It was developed to assist network interfacing by providing a standard for network structures. The ISO model subdivides the functions of a network system into seven layers (See Figure II-1). This subdivision of network functions simplifies the overall task of interfacing systems on a network. The reason being the interfacing is done in increments, hence the implementation of each separate network function is less complicated.

application layer	layer 7
presentation layer	layer 6
session layer	layer 5
transport layer	layer 4
network layer	layer 3
data link layer	layer 2
physical layer	layer 1

Figure II-1. ISO Model.

Physical Layer Protocol. The physical layer provides mechanical, electrical, functional, and procedural characteristics to establish, maintain, and release physical connections (65:430). This includes the scheme used by a network for allowing the use of the transmission medium. Other issues which are covered by the physical layer are constraints on the physical medium and location of computer devices on a network.

Data Link Layer Protocol. The purpose of the data link layer is to provide the functional and procedural means to establish, maintain, and release data links between network entities (65:430). A data link between devices on a network can be in one of two forms, connection oriented or connectionless.

In a connection oriented method, a data link between computer devices must first be initiated before data can be sent over a communications link. Once data transfer has

been completed over a data link, the data link must be terminated.

In a connectionless scheme, a single frame of data is passed from one device on the network to another. The connectionless scheme is described in the IEEE 802 Data Link Control Protocol (35). There is no handshaking to ensure data sent was received by the destination station when a connectonless scheme is used. This scheme is normally used on high transmission rate networks, such as local area networks. The reliability that data will be received by a device on the network, when a connectionless scheme is used, is ensured by higher layer protocols of a local area network.

The data link layer also addresses the issue of data framing. Data framing specifies the field contents of a frame of information to be transmitted on the network. Fields are separated by control characters, or by specifying the length for each field in a frame. A frame of information usually contains the source and destination device address fields, the data field, and the error check field.

Network Layer Protocol. The network layer provides routing and switching of information in a network system (65:430). The network layer is composed of two sublayers. One sublayer is concerned with network traffic for a local network. The other sublayer is concerned with network traffic between network systems, which is called an internetwork, or internet.

The network layer, like the data link layer, may use a connection oriented or a connectionless scheme for network traffic routing and switching. In a connection oriented scheme a logical link is established between the source and destination devices on a network. Once a link has been established, blocks of information called packets, are transmitted from the source device to the destination device. The link is not terminated until all packets tramsmitted have been acknowledged by the destination device.

In a connectionless scheme, packets are transmitted independently. This is known as datagram delivery. The routing used to transmit individual packets may also be different, because logical packet routes are not predefined. This scheme allows for a simpler strategy for routing packets. The reason being routing information, such as state tables, do not have to be maintained.

Transport Layer Protocol. The transport layer is concerned with the reliable and cost effective transfer of data in the network (65:430). There are five types of transport services: connection oriented, connectionless, broadcast, multicast, and expedited (14:25).

A connection oriented service initiates, maintains, and terminates a connection between transport layers of a network system. A connection is not terminated until all the information has been reliably tramsmitted between two devices on a network.

A connectionless service provides the reliable transfer of one packet of information between computer devices on a network.

The broadcast service transfers a packet of information to all computer devices on the network. This service does not ensure that the packet broadcasted was reliably received by all devices on a network.

The multicast service transfers a packet of information to a group of computer devices on a network. This service also does not ensure that the packet transmitted was reliably received by all devices which make up a multicast group.

The expedited service provides a means for exchanging information between transport layers in a short time periord. This is accomplished by limiting the packet size when using this service.

The transport layer provides reliable transfer of data through the use of certain functions. Some of the basic functions used by a reliable transport layer are sequence control, error detection and error recovery, and information assembly/disassembly (14:27).

The sequence control function ensures that all the packets, which makes up a block of information, were received by a destination device on the network. This function is carried out by assigning consecutive sequence numbers to packets as they are transmitted. The sending computer device's transport layer checks to make sure all

the packets were received by keeping track of the sequence numbers received by the destination computer device's transport layer. If the destination computer device did not receive all of the packets of an information block, then the sending computer device transmits those packets which were not received.

The error detection function is carried out by adding a field to the transport layer packet for data validation, such as a checksum or a cyclic redundancy check field. Depending on the type of check field used for data validation, the transport layer may also be able to do error recovery. This can only be done with check schemes which cannot only detect errors, but also detect where the errors are in a packet of information.

The assembly function encapsulates data from the session layer into transport layer packets. The disassembly function concatenates the data fields of transport layer packets to form an information block.

Session Layer Protocol. The session layer provides control for binding and unbinding between two presentation entities, as well as controlling the exchanging, delimiting, and synchronizing of data between two presentation layers (65:430). The binding control of a session allows two presentation layers to communicate through a dialogue. The unbinding control of a session is the means by which communication between two presentation layers is terminated.

The presentation layers at either end of a dialogue

controls the state of a session. One presentation layer wanting to establish a dialogue with another presentation layer does so by issuing a request to its session layer. The session layer then establishes a path by which communications between the requesting and the destination presentation layers can carry on a dialogue. This path is established through the use of the transport layer.

Once a communication path has been established by the session layer, the presentation layers can carry on a dialogue. The presentation layers use the structure the session layer defines for data and message exchange.

The presentation layers terminate a dialogue by issuing the appropriate message to the session layer. The session layer then terminates the connection established by the transport layer.

Presentation Layer Protocol. The presentation layer provides services which may be selected by the application layer to enable it to interpret the meaning of data exchanged (65:430). The presentation layer provides a structuring of data that can be used by the application layer to transfer information.

The application layer conveys to the presentation layer the data structure it wishes to use to transmit/receive information. The presentation layer then makes the appropriate transformation of the data depending on whether the data is being transmitted or received. If the data is being transmitted, then it is transformed into a format

suitable for transmission by the session layer. If the data is being received, then it is transformed from the session layer format to the format specified by the application layer.

Application Layer Protocol. The protocols of this layer directly serve the end user by providing the distributed information service appropriate to an application, to its management, and to system management (65:430). Application services that might be provided for an end user are electronic filing, mailing, and printing. System management tools at the application level might allow collection of statistics on network operations and resource usage information. This type of information can assist the manager of a network system in configuration management, resource management, and workload management of the network.

Xerox Network Structure

Overview. Xerox has developed a network structure that not only allows interfacing with Xerox office automation computers in a local area network environment, but also allows the internetworking of Xerox Network Systems (XNS) with other network systems. The Xerox network structure is a layered protocol structure. The Xerox layered protocol structure encompasses the network functions outlined by the ISO model. The level zero protocols contain the protocols for particular network systems. This is comparable to the physical layer, data link layer, and the network layer of

the ISO model which deals with a single network system. The level one protocol is comparable to the network layer of the ISO model that deals with internetworking of network systems. The level two protocols are comparable to the transport layer of the ISO model. The level three protocols are comparable to the session and the presentation layers of the ISO model. The level four protocols are comparable to the application layer of the ISO model.

The Program and Financial Control office uses the Ethernet at level zero of their Xerox Network System. Their network system contains only Xerox office automation equipment. All of the Xerox office automation equipment on their network contains, at a minimum, level one to level three of the Xerox network structure. Level four protocols are also resident on Xerox office automation devices on their network as appropriate. Therefore, in order for the Program and Financial Control office to have the VAX 11/780 communicate with other devices on their network, it must also contain the Xerox network structure.

The following discussion relates the Xerox network structure to the seven layer ISO model. It is assumed, as in the case of the Program and Financial Control office, that the Ethernet is used at level zero for the transmission of level one to level four protocols of the Xerox network structure.

XNS Physical Layer. The physical layer handles the transmission/reception of Ethernet packets on the Ether.

This is accomplished by functional components that produce/receive signals on/from the Ether. The functional components are an encoder/decoder, synchronization circuitry, tranceiver cable, carrier sense circuitry, and the tranceiver (51:31). The encoder/decoder is usually located on a controller board, which also contains the data link layer. Each bit sent by the data link layer to the physical layer is encoded using a Manchester encoding scheme. This scheme merges the separate bit data and clock signal into a single, self-synchronization serial bit stream suitable for transmission on the coaxial cable by the transceiver (51:96).

The controller board also contains circuitry which creates/removes a 64 bit pattern before a data link layer packet is transmitted/received (See Figure II-2). This 64 bit pattern is called the preamble. The preamble has alternating 1's and 0's for the first 62 bits. The last two bits of the preamble are set to 1's. These two bits signal the beginning of a packet. The preamble is sent through the encoder to the tranceiver before the first bit of a data link layer packet is sent. The preamble is discarded upon receipt by the physical layer. The preamble is used for synchronization to ensure data on the Ether is valid to all stations on the network.

The transceiver cable connects the controller board to the transceiver. The transceiver cable carries three signals, and power to the transceiver. The three signals

are the receive, transmit, and collision signals. The transmit signal carries the encoded bits which are to be placed on the Ether by the transceiver. The receive signal carries the encoded bits received by the transceiver from the Ether. This signal is sent to the decoder and also a carrier sense circuitry at the controller. The carrier sense circuitry signals the data link layer that data is available. However, the data link layer must check the address field of the packet to determine if the packet is addressed to the station. The collsion signal is activated by the transceiver when it detects an input transition before 160 nanoseconds has elasped.

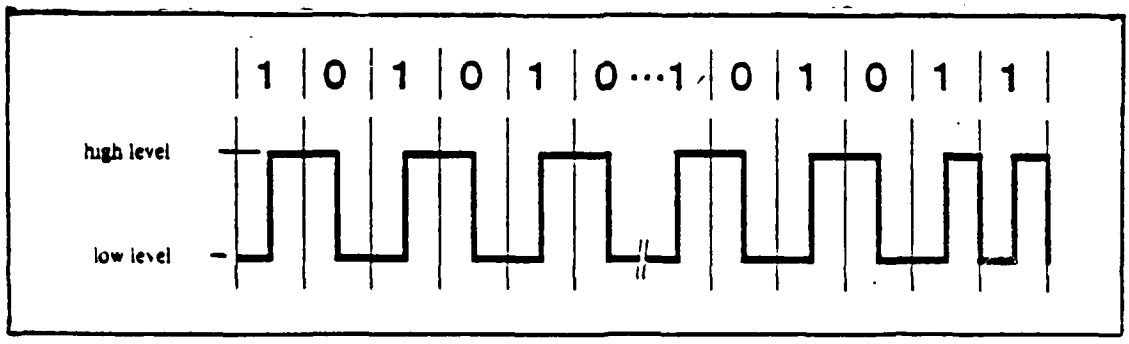

Figure II-2. Preamble Encoding

Source: 51:98

The physical layer of the Ethernet not only addresses the requirements of connecting a station to the Ether, but also how an Ethernet system can be configured. Certain limits are placed on an Ethernet configuration to ensure a

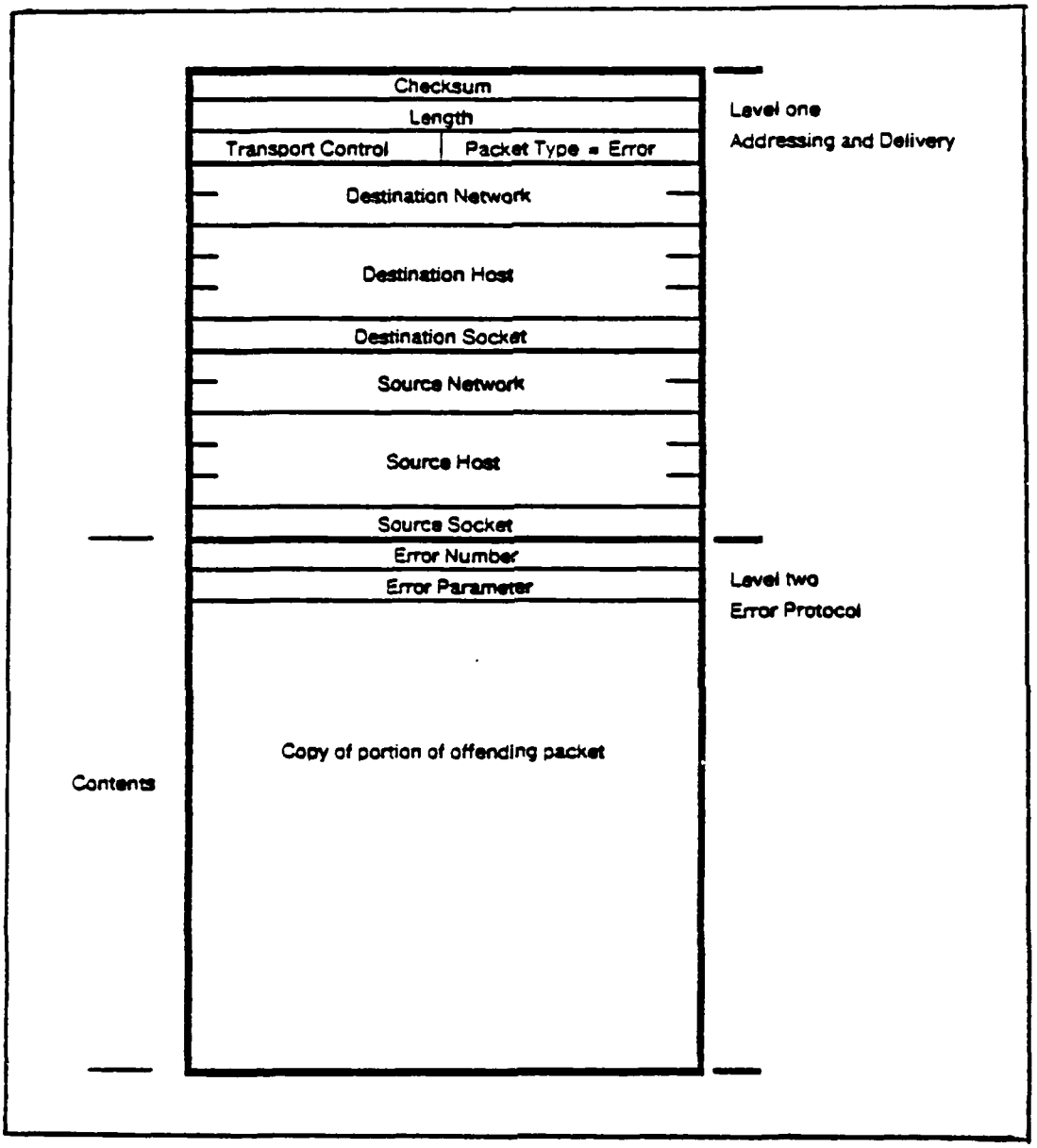

Figure II-10. Error Packet

Source: 54:33

operation. A request operation requests routing information about other networks in the internetwork from an internet router. The networks that information is requested about is specified in the object network field(s). An internet router responses to a request operation by specifying, in the internetwork delay field(s), how many internetwork router "hops" it takes to get to the network(s) specified in the object network field(s). If a internetwork delay field was set to 16, then a requested network in the object network field could not be reached by the internetwork router. The internetwork router sets the operation field to response, and sends the network information back to the source host address.

XNS Error Protocol. The Error Protocol is used for reporting the occurrence of an error during the transmission of internet packets. The Error Protocol specifies an internet packet format (See Figure II-10). An internet packet with the packet type set to 2 octal denotes an error packet. Any socket within a host may generate an error packet in response to some error condition. The error packet is addressed to the source network, host, and socket which caused the error condition. The error number field represents these conditions (See Table II-1). The error parameter field, of the error packet, may be set to indicate the type of parameters to use to determine the kind of error which occurred. The contents field contains a portion of the internet packet which caused the execution of the Error Protocol.

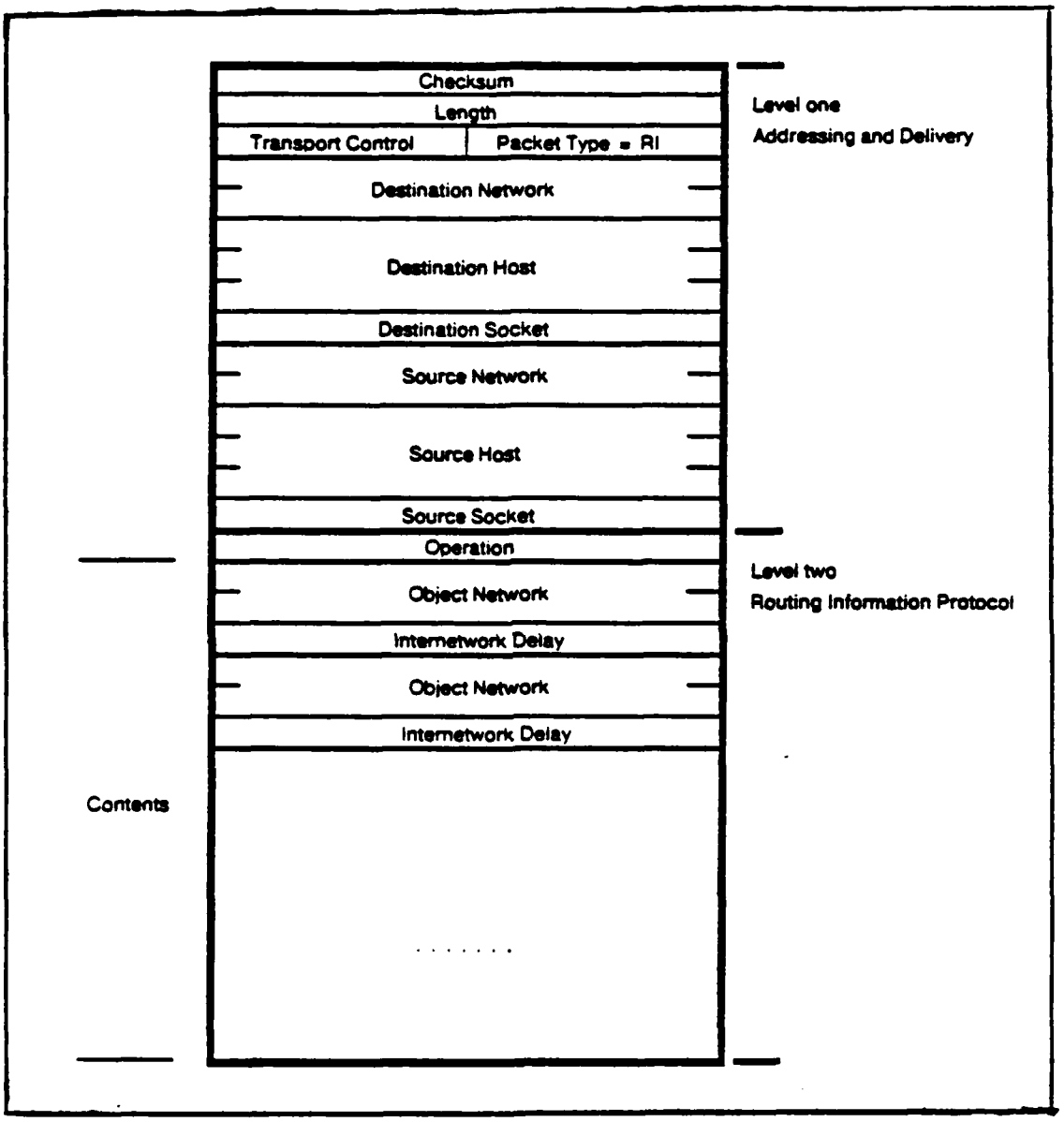

Figure II-9. Routing Information Packet

Source: 54:26

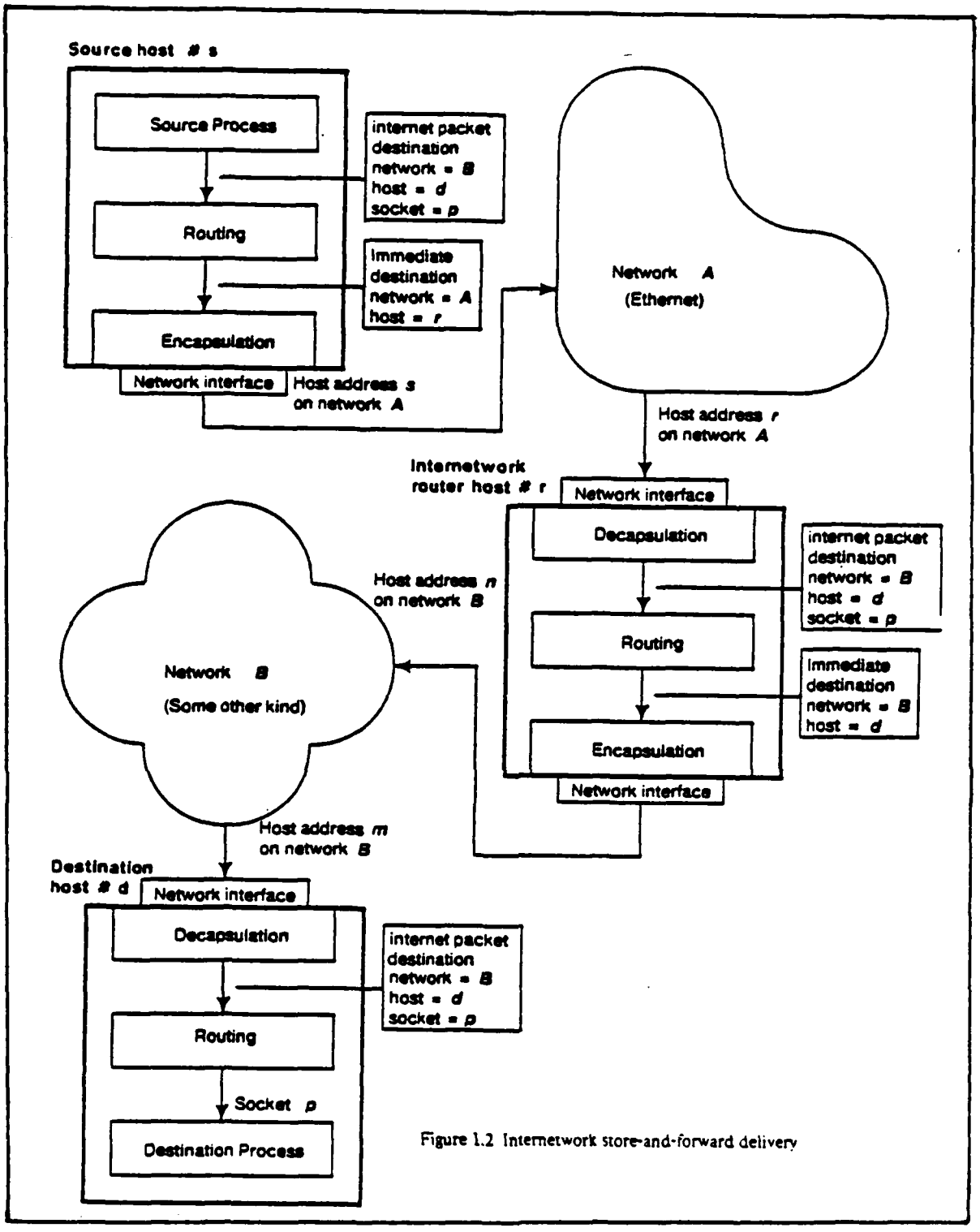

Figure 1.2 Internetwork store-and-forward delivery

Figure II-8. Internetwork

Source: 54:7

structure. The five protocols are part of what Xerox calls its Internet Transport Protocols. The five protocols of the transport layer provides reliable service by performing functions such as retransmission, sequencing, duplicate suppression, and flow control of internet packets (54:2).

XNS Routing Information Protocol. The logical function of switching (routing) internet packets between sockets (that are on the same host), between sockets and networks (the host is the source or destination of the packet), and between networks themselves (in an internetwork router) is abstractly captured in a router (54:5). Each host system on an internetwork contains a router. Host systems on the internet which are responsible for store-and-forward delivery of internet packets between networks also contains what is called an internet router (See Figure II-8).

The Routing Information Protocol provides a means for host routers and internetwork routers to exchange routing information. Each router on an internetwork maintains a routing table of network addresses used by the resident host. An internetwork router also maintains addresses of all the networks it is connected to.

The Routing Information Protocol specifies an internet packet format (See Figure II-9). An internet packet with the packet type field set to 1 octal denotes a routing information packet. The operation field of a routing information packet designates either a request or response

"hop" count of 15, the packet is discarded. The maximum number of networks an internetwork packet can traverse is 16.

The packet type field is specified by the transport layer protocols. It defines the type of internet packet being transmitted. This field is not interpreted by the Internet Datagram Protcol, but rather by the transport layer protocols at a destination station.

The address information of an internet packet contains source and destination network, host, and socket addresses. The network address specifies the unique address of one of the networks which makes up an internetwork. The host address specifies the unique address of one of the host systems (stations) on an internetwork. The socket address specifies a unique socket within a host system. A socket is a uniquely identified object within a host, to which internet packets can be delivered, and from which internet packets may be transmitted (13:2). An internet packet can be addressed to a host system, to a group of host systems (multicast), or to all the host systems on the internetwork (broadcast).

XNS Transport Layer. Xerox Network Systems provide five protocols for the reliable transmission of information on the internetwork. The five protocols are Routing Information Protocol, Error Protocol, Echo Protocol, Sequence Packet Protocol, and Packet Exchange Protocol. These protocols make up level two of the Xerox network

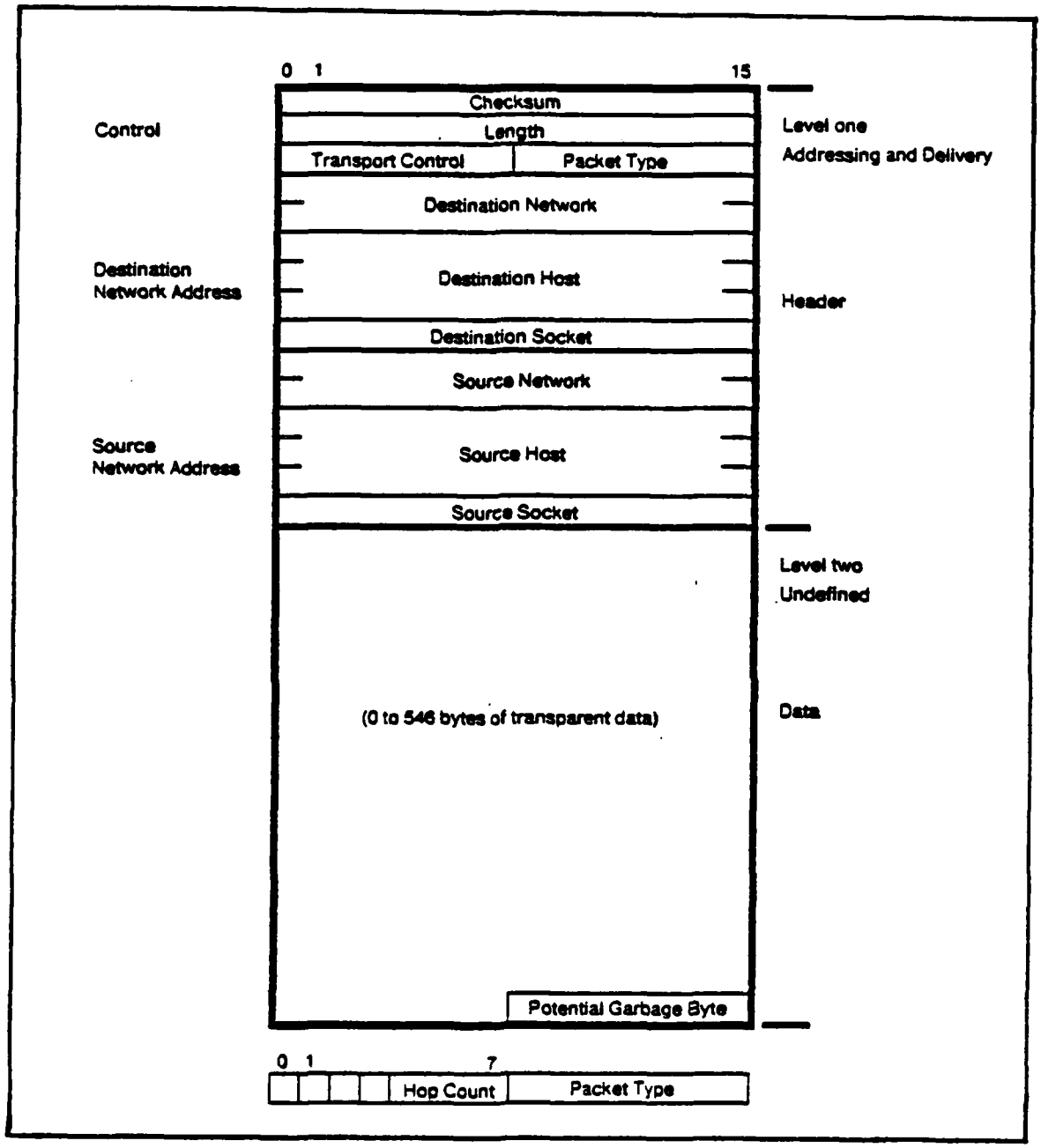

Figure II-7. Internet Packet

Source: 54:15

function of the Internet Datagram Protocol is to address, route, and deliver standard internet packets, each of which is treated as an independent entity with no relation to other internet packets traversing the system (54:14). An internet packet is indentified as the data field of an Ethernet packet when the type field of an Ethernet packet has a value of 3000 octal.

The Internet Datagram Protocol specifies the format of the internet packet (See Figure II-7). The internet packet format is composed of three areas: control information, address information, and data. The control information of an internet packet contains the checksum, length, transport control, and the packet type fields. The checksum field is used to detect whether the other fields of an internet packet is valid. If an internet packet is found to be erroneous, it is discarded without error reporting. Error reporting should be handled by the transport layer. The length field specifies the size of internet packets in bytes. An internet packet may contain a garbage byte to insure that all internet packets are of an integral size of 16 bit words. The garbage byte is not included in the length field.

The transport control field is used to keep track of how many networks an internet packet has transversed. Each time an internet packet is being transmitted to another network, the network router increments the "hop" count. If a network router receives an internet packet which has a

XNS Network Layer

Local Networking as Applied to the Ethernet. The Ethernet uses a connectionless scheme for routine packets. The network dedicates itself to routing one packet at a time. However, it does not ensure that the packet will be transmitted correctly, or at all. Once a packet has been placed on the Ethernet, every station on the network will receive it. The destination address field of an Ethernet packet determines the destination station(s) of a packet. The Ethernet provides three forms of addressing, station to station, multicasting, and broadcasting (10:13). In station to station addressing, the destination station field of an Ethernet packet designates the destination station. In multicasting addressing, the destination address field of an Ethernet packet designates a group of stations that makes up a multicast group. In broadcasting addressing, the destination address field of an Ethernet packet is set to zero, this indicates that the packet is for every station on the network.

XNS Network Layer

Internetworking as Applied to Xerox Network System. Xerox Network Systems use a datagram technique for delivering internetwork packets. The datagram technique is a connectionless scheme for internetwork traffic routing and switching. The scheme for handling internetwork packets is outlined in the Xerox Internet Datagram Protocol (54). The

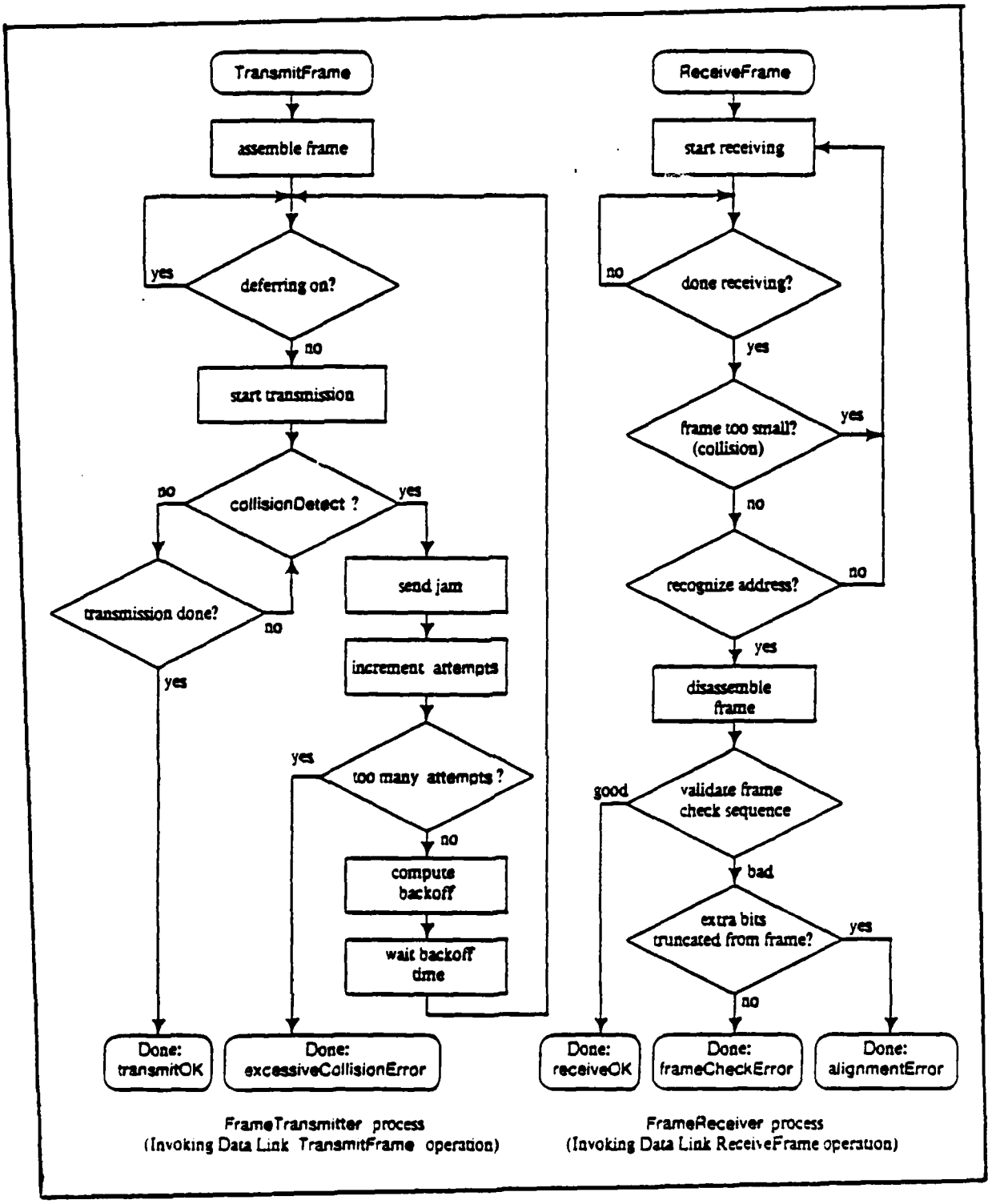

Figure II-6. Ethernet Data Link Layer

Source: 16:32

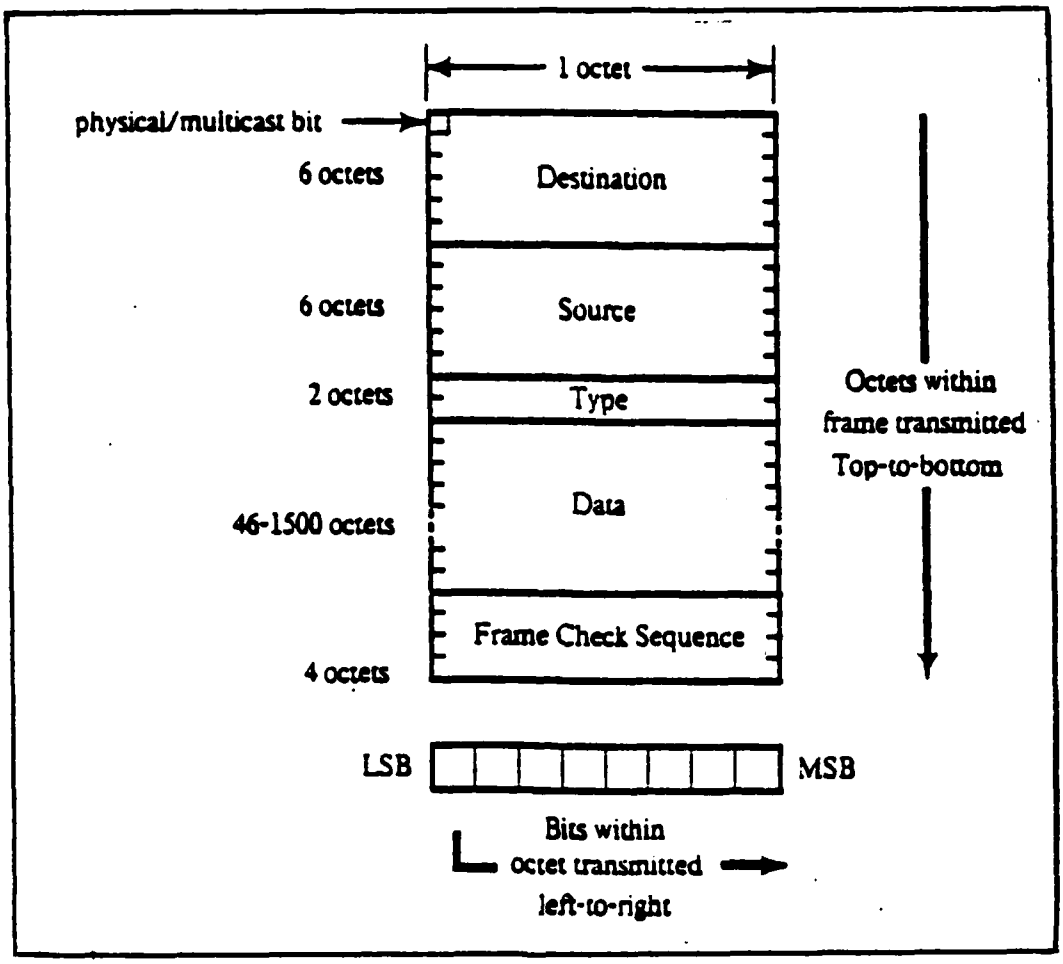

Figure II-5. Ethernet Packet

Source: 16:20

adds the frame check sequence field when constructing packets to be sent to the physical layer. The frame check sequence field is used to perform a cyclic redundancy check (CRC) to detect errors in a packet received from the physical layer. This check is performed using all fields of the packet except the CRC field. The function used for generation of the CRC field and validation of the other fields is the same one used in the Autodin-II network (25).

The other function which makes up the data link layer on the Ethernet is called link management (See Figure II-6). Link management involves two task, transmitting/receiving packets to/from the physical layer and handling data collisions. The packets communicated between the data link and physical layers are sent 1 bit at a time. The data link layer can send a packet to the physical layer for transmission only when the physical layer is not receiving data from the Ether. The transmission of a packet between the data link and physical layers is clocked, therefore no handshaking is required before each bit is transmitted. However. when the data link layer is transmitting a packet to the physical layer. it must monitor the transmission checking for the occurrence of a collsion. If a collision occurs, the data link layer determines when to try retransmitting the packet.

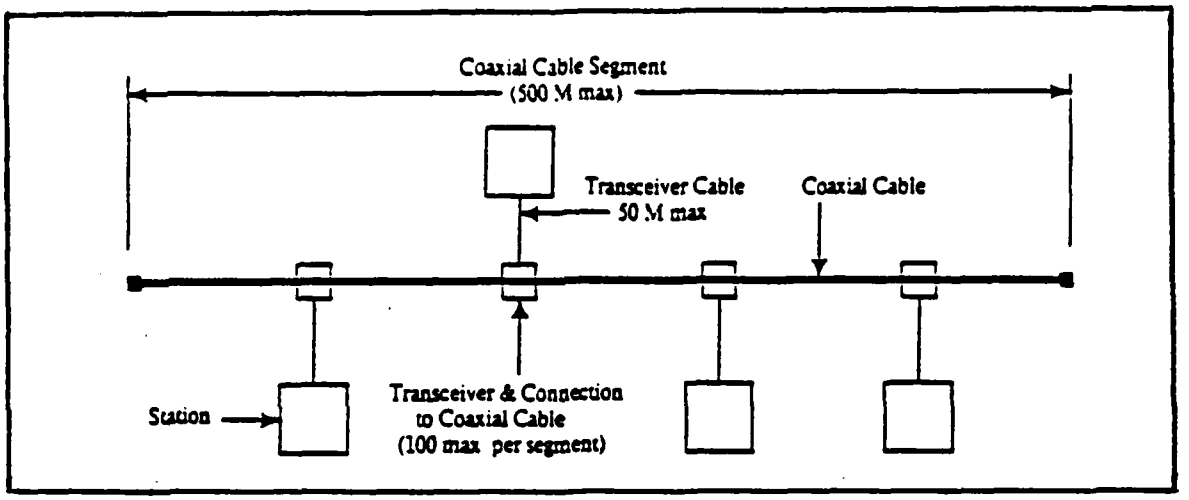

Figure II-3. A Single Cable Segment

Source: 51:79

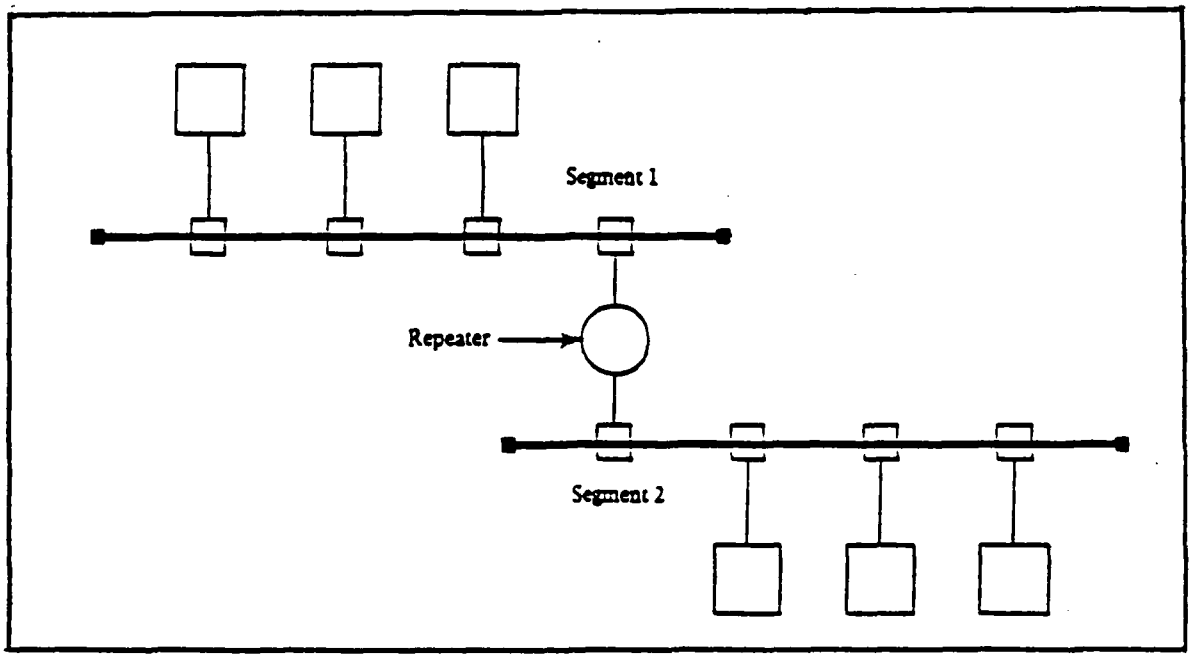

Figure II-4. Two Cable Segments

Source: 51:79

consistent 10 Mbps transmission rate, and a limit on the propogation delay of information on the Ether. For instance, a cable segment cannot exceed 500 meters (See Figure II-3). It also cannot contain more than 100 transceivers.

The Ethernet does provide a way to connect cable segments, by using a repeator device (See Figure II-4). A repeator device repeats the signals from one cable segment to another. However, the maximum number of repeators allowed within the path of any two stations is two (51:77).

XNS Data Link Layer. The data link layer uses a connectionless scheme for flow of data on an Ethernet. The data link layer is composed of two main functions which allows the transmission/reception of information to/from the physical layer, called data encapsulation and link management (16:19). Data encapsulation involves taking information supplied by the network layer and creating an Ethernet packet for the physical layer to transmit on the Ether. Data encapsulation also involves decapsulation of data out of an Ethernet packet supplied by the physical layer. The decapsulated data is sent to the network layer.

The Ethernet provides a variable size packet for data transmission on the Ether (See Figure II-5). The packet structure is represented in octets. Each octet represents 8 bits. An Ethernet packet can have from 512 bits to 1200 bits in the data field. The data encapsulation function

Table II-1

Error Types

Error Number	Description
0	An unspecified error is detected at detected at destination.
1	The checksum is incorrect, or the packet has some other serious inconsistency detected at destination.
2	The specified socket does not exit at the specified destination host.
3	The destiantion cannot accept the packet due to resource limitations.
1000	An unspecified error occurred before reaching destination.
1001	The checksum is incorrect, or the packet has some other serious incon sistency before reaching destination
1002	The destination host cannot be reached from here.
1003	The packet has passed through 15 internet routers without reaching its destination.
1004	The packet is too large to be forwarded through some intermediate network. The Error Parameter field contains the length of the largest packet that can be accomodated.

Source: 54:34

XNS Echo Protocol. The Echo Protocol is used to ensure a host system exist on the internetwork. The Echo Protocol specifies an internet packet format (See Figure II-11). An internet packet with the packet type set to 3 octal denotes an Echo Protocol packet. The operation field, of the echo packet, can be set to echo request or echo reply. If a host wants to determine the existence of another host, then an echo packet must be constructed with the operation field set to echo request, and the data field set to information to be echoed. When a host system receives an echo packet with the operation field set to echo request, it will set the operation field to echo reply and transmit the packet back to the source host system. When the host system, which initiated an echo packet with echo request and data to another host, receives an echo packet with echo reply and the original data sent to the destination host, then the host system does exist on the internetwork. However, if the an echo packet with echo reply is not received from the destination host of an Echo Protocol exchange, then the host does not exist on the internetwork.

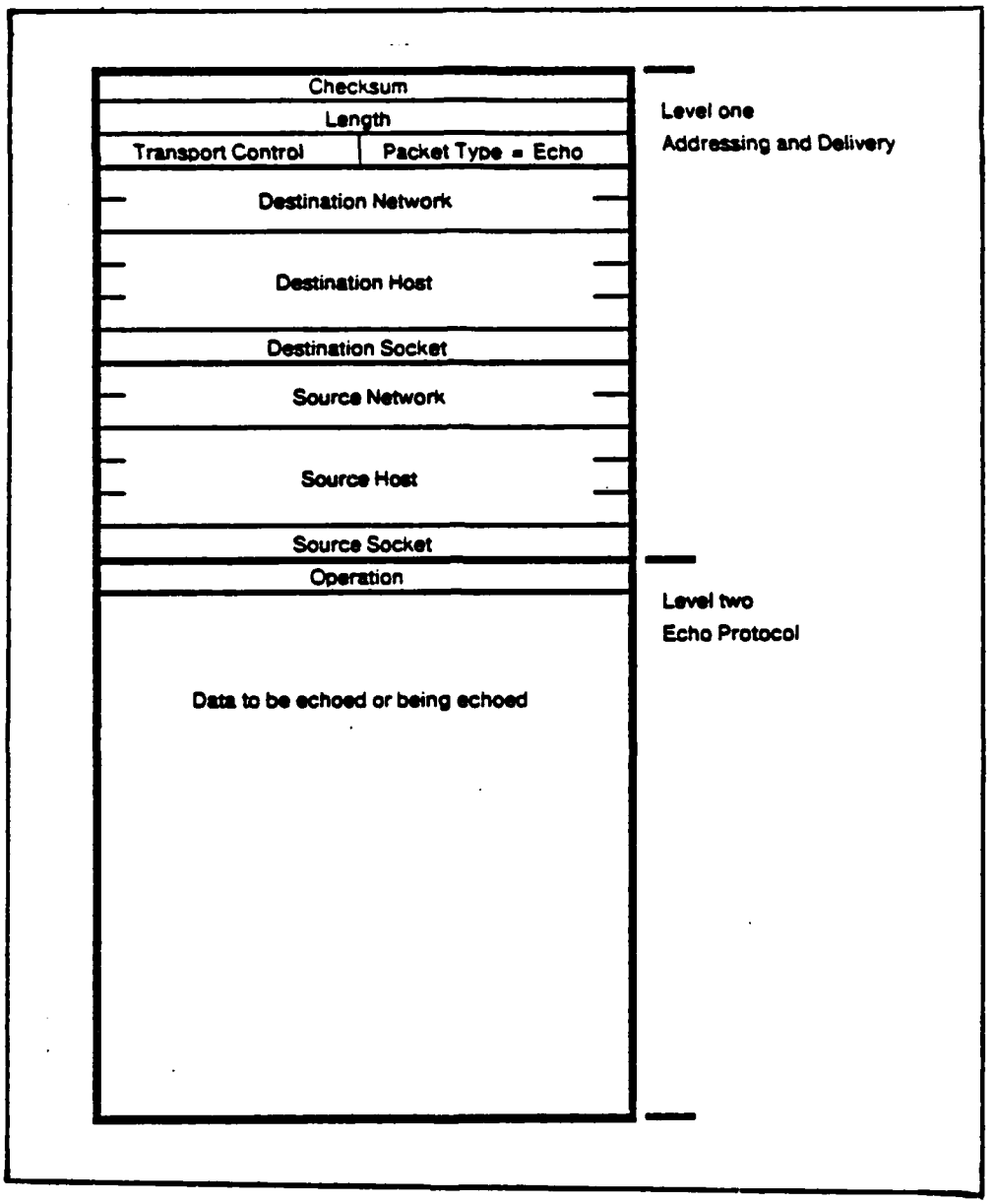

Figure II-11. Echo Packet

Source: 54:35

XNS Sequenced Packet Protocol. The Sequenced Packet Protocol provides a reliable way of transmitting internet packets. This is achieved by establishing a connection between a send device's transport layer and a receiving device's transport layer. Therefore, the Sequenced Packet Protocol uses a connection oriented scheme for the reliable transmission of internet packets. The Sequenced Packet Protocol transmits informaton that is received from the session layer. The transport layer assembles the data it receives into internet packets. Each packet is sent to a destination station with a sequence number. The first packet sent has a sequence number of zero, and successive packets sequence numbers are one higher then the packet sent before it. Acknowlegement of received packets by the destination station is sent to the source station by sending an echo of the packet received. If the sequence number of a packet echoed to the source station was higher than expected, then packets were lost or in error. Therefore, the lost or error packets must be retransmitted by the source station.

The Sequenced Packet Protocol specifies an internet packet format (See Figure II-12). An internet packet with packet type set to 4 octal denotes a Sequenced Packet Protocol packet. The connection control field is 8 bits. The system packet bit, bit 0 of the connection control field, is used to determine which station the internet packet is for. The send acknowledgement bit, bit 1 of the

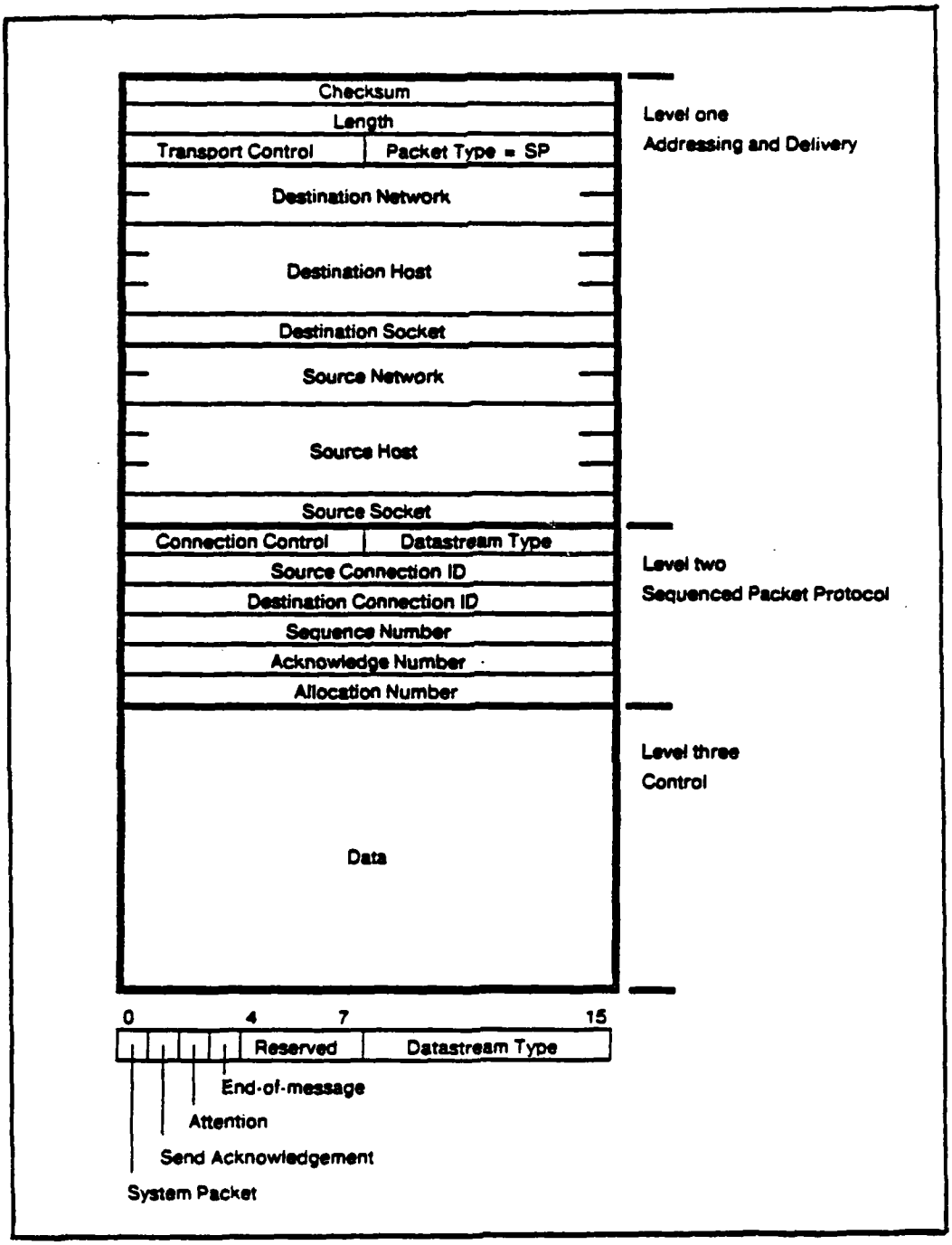

Figure II-12. Sequenced Packet

Source: 54:38

connection control field, tells the destination station to acknowledge every packet received. The attention bit, bit 2 of the connection control field, tells the destination station to notify the session layer of arrived packets. The end of message bit, bit 3 of the connection control field, tells the destination station to convey to its session layer that it is at the end of a message stream of packets.

The datastream type field is not used by the Sequenced Packet Protocol. The field is transmitted from the source sequence packet protocol to the destination sequence packet protocol, where it is sent to the session layer for interpretation. This field is used for communications between session layers of a connection.

The source and destination IDs indentifies the sockets of the source and destination stations that established a connection.

The sequence number field keeps track of the number of packets sent in either direction on a connection. The destination station can also send sequenced packets to the source station. Therefore, the connection provides a two way packet communications path. The sequence number field is used by the destination station to deduce the order of packets, to acknowledge them, to suppress duplicates, and to specify flow control information (54:40).

The acknowledge number field specifies the next sequence packet the destination station is expecting from the source station.

The allocation number field specifies the number of packets that will be accepted at a destination station. During the operation of a connection, this number may go up, but not down.

The data field contains session layer data.

XNS Packet Exchange Protocol. The Packet Exchange Protocol is used for requesting service from a socket. The Packet Exchange Protocol specifies an internet packet format (See Figure II-13). An internet packet with the packet type set to 5 octal denotes a Packet Exchange Protocol packet. The ID field specifies the socket that service is requested of. The client type field specifies the service requested. The response to a request is sent to the destination socket address. If the response sent to the destination socket address has the ID and client type fields of the original request, then the data field contains a valid response from the service socket.

XNS Session Layer Protocol. Although, Xerox claims that it does not implement the session layer of the ISO model, in fact it really does implement the session layer of the ISO model. It was stated in the Xerox Internet Transport Protocols document that Xerox has no protocol corresponding to layer 5 of the ISO model, the session layer (54:9). However, the Xerox Courier Protocol, which was stated in the same document as implementing the presentation layer, also implements the session layer. The Xerox Courier

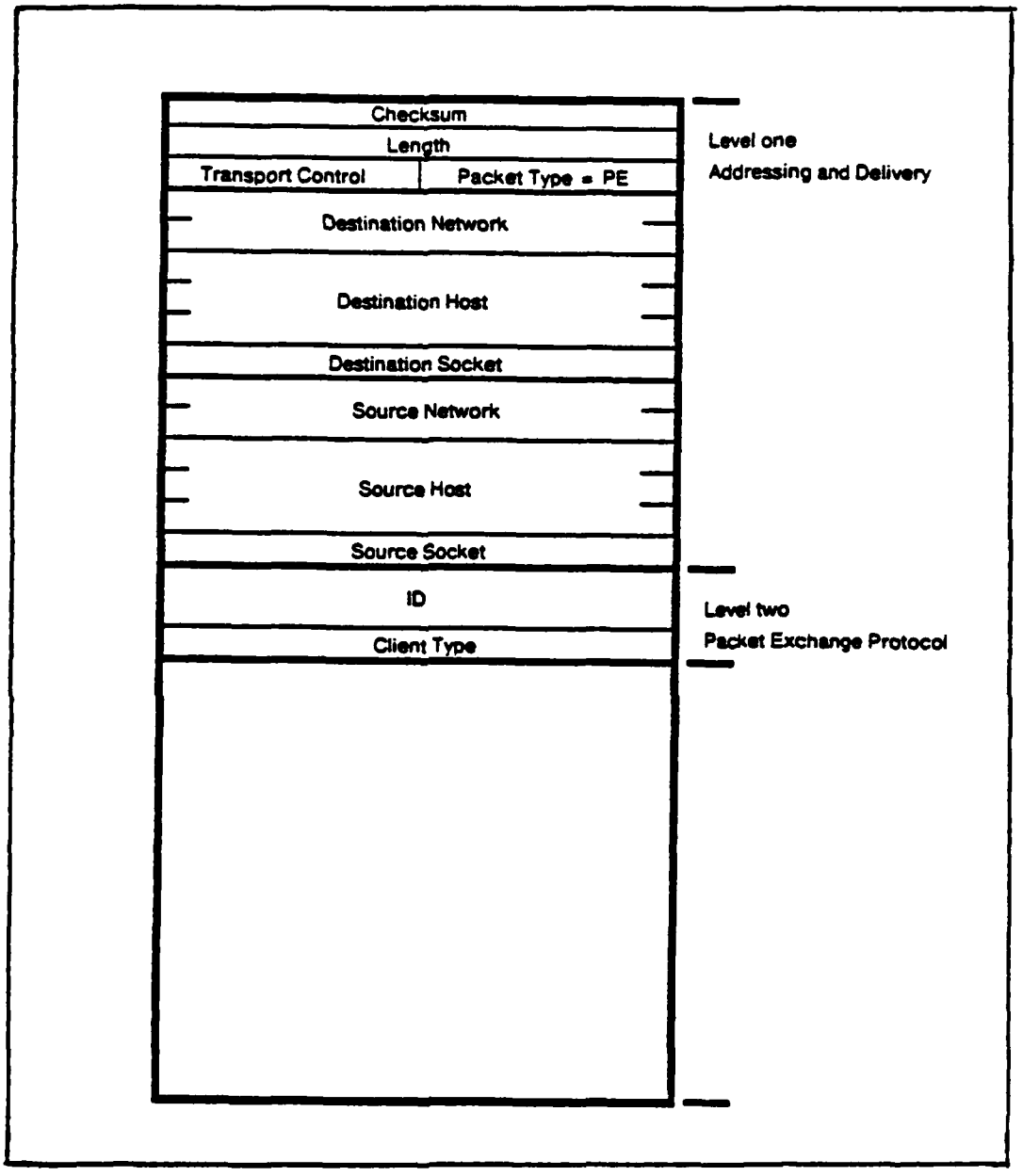

Figure II-13. Packet Exchange Protocol Packet

Source: 54:50

Protocol implements two types of session layer services, one that sets up a session for data exchange, and another that provides transaction processing services.

The establishment of a session for exchanging of data between two sockets is referred to as layer one of the Courier Protocol. Layer one defines a block stream that can carry blocks of arbitrary binary data between system elements (sockets) (55:3). A block of data consists of data bits which are multiple of 16 bits. First, a session must be established between two Courier Protocols. This is achieved by establishing a connection at the transport layer. using the Sequenced Packet Protocol. Once a connection has been established, the version of Courier to be used must be agreed upon by the sending and receiving stations. After the version of Courier to be used has been agreed on, the data blocks are transmitted between the sending and receiving stations by using the Sequenced Packet Protocol. After all the data has been sent between the sender and receiver, the sending station transmits an "end" packet to the receiving station. Once the receiving station has received all of the data blocks, it transmits an "end-reply" packet to the sending station. After the sending station receives the "end-reply" packet from the receiving station, it then sends another "end" packet to the receiving station to terminate the session.

Courier also provides a session service for transaction processing. This service is layer three of the Courier

Protocol. Layer three defines a message stream capable of carrying service requests (that is, call messages) and replies (for example, return and abort messages) between system elements (55:3). Courier defines four message types for transaction processing: call, reject, return, and abort. The call message invokes a socket program. The reject message is sent back when the requested socket program can not be executed. The return message is sent back to acknowledge the successful completion of a socket program. The abort message is sent back when an error condition occurs doing the execution of the socket program. The Packet Exchange Protocol, of the Xerox Internet Transport Protocols, provides service for remote socket calls, which is what this type of session service is.

XNS Presentation Layer. The functions of the presentation layer are also contained in the Courier Protocol. Layer two of the Courier Protocol implements the presentation layer functions. Layer two defines an object stream capable of carrying structured data (for example, booleans and cardinals) between system elements (sockets) (55:3). An object stream is composed of data objects. Each data object represents a data typing such as integer, string, or array. Each data object is encoded into multiple bits of 16. The data objects are then sent to layer one of Courier for transmission, by using the Sequenced Packet Protocol of the Xerox Internet Transport Protocols. Remember, layer one of Courier breaks data objects into data

blocks for transmission. Therefore, when the data blocks are received at the destination station, they are assembled into data objects and decoded by the layer two Courier Protocol to transform them into their correct data type.

Xerox has also developed a dialogue that application layer protocols can use to transfer large amounts of information, called bulk data. This dialogue is defined by the Xerox Bulk Data Transfer Protocol (56). The Xerox Bulk Data Transfer Protocol defines a dialogue that the sender and the receiver of bulk data can use to contact each other, as well as controlling the transfer of the bulk data.

XNS Application Layer. Xerox Network Systems have many applications available to the user. Some of the applications available are file service, print service, and electronic mailing. File service allows workstations on the network to store and retrieve information on mass storage areas called file servers. The use of file servers on an internetwork by workstations also allows sharing of information stored on the file servers between workstations. Print service allows workstations to share printers on the network. Print service allows users to send files from their own workstation, or files located on file servers, to a printer on the network for printing. Electronic mailing

allows mailing of documents, files, and messages to other workstations on the network.

TCP/IP Requirements

The Program and Financial Control office is part of the Department of Defense (DoD). DoD has adopted its own protocols for the internetworking of packet switched network systems. DoD uses the Internet Protocol (IP) at the network layer. DoD also uses the Transmission Control Protocol (TCP) at the transport layer. These two protocols are commonly referred to as TCP/IP. TCP/IP was developed by the Defense Advanced Research Projects Agency (DARPA) (46, 6, 7). It has been mandated that the use of DoD standard host-to-host protocols (TCP/IP) is mandatory for all DoD packet-oriented data networks which have a potential for host-to-host connectivity across network or subnetwork boundaries (38). Therefore, the Program and Financial Control office must comply with this mandate.

Xerox Network Systems use the Xerox Internet Transport Protocols (ITP) and the Xerox Internet Datagram Protocol (IDP) at the transport and network layers. Xerox Network Systems use these protocols for routing internetwork traffic and for providing reliable transmission of higher layer protocols information. Therefore, the Program and Financial Control office is negotiating with Xerox to provide a device on a Xerox internetwork which will accept TCP/IP internet packets and encapsulate them into ITP/IDP internet packets

for routing. However, the Program and Financial Control office would like the VAX 11/780 to be accessible to networks in the interwork using TCP/IP. Therefore, TCP/IP must also be implemented on the VAX 11/780 along with higher layer protocols supported by TCP/IP such as File Transfer Protocol (FTP), Simple Mail File Transfer Protocol (SMTP), and the Terminal/Host Protocol (TELNET) (6).

Summary

The ISO model for network architectures defines a layering of protocols. This model was developed as a standard to assist in the internetworking of network systems. The layering of protocols outlined by the ISO model is commonly used for the design and implementation of network structures.

Xerox has develop a network structure based on the layering of protocols defined by the ISO model. The Xerox network structure has five levels, beginning with level zero. Level zero corresponds to layer one, layer two, and layer three that deals with local area networks, of the ISO model. Level one corresponds to layer three of the ISO model that deals with internetworking. Level two corresponds to layer four of the ISO model. Level three corresponds to layers five and six of the ISO model. Level four corresponds to layer seven of the ISO model.

The Program and Financial Control office has requirements, as outlined in Chapter one, for using a VAX

11/780 system to interface with a Xerox Network System. The interfacing will occur at level four of the Xerox network structure. The interfacing with level four applications requires the existence of levels three thru zero of the Xerox network structure on the VAX 11/780, because the Xerox network structure is layered. Therefore, all four levels of the Xerox network structure must be implemented on the VAX 11/780 if the Program and Financial Control office requirements' of interfacing a VAX 11/780 with their Xerox Network System is to be met.

The Program and Financial Control office, being part of the Department of Defense, is mandated to use the TCP/IP protocols at the network and transport layers for internetwork communications. Therefore, an implementation of TCP/IP for the VAX 11/780, using Berkeley Unix 4.2BSD, is also required.

The Program and Financial Control office is, first, interested in the interfacing of the VAX 11/780 with Ethernet based Xerox Network Systems. Second, interested in having a capability of interfacing with other networks via the TCP/IP protocols. Hence, the rest of this thesis is geared toward the accomplishment of the goal of interfacing the VAX 11/780 with Ethernet based Xerox Network Systems. The interfacing of Xerox Network Systems and networks using TCP/IP is a thesis effort in itself. Since the Program and Financial Control office would like the VAX 11/780 to eventually interface with host systems on TCP/IP networks,

Table III-4

XNS Level Two Summary

XNS Level Two	A	B	C	I	N
Sequenced Packet Protocol	F	F	N	F	F
Echo Protocol	F	F	N	F	F
Packet Exchange Protocol	N	F	N	F	F
Error Protocol	P	F	N	F	F
Routing Information Protocol	P	F	N	F	F

Definition of Symbols:

A = Advanced Computer Corporation
B = Bridge Communications
C = 3Com Corporation
I = Interlan
N = Network Research Corporation
F = Full Implementation
P = Partial Implementation
N = No Implementation

XNS level one is specified by the Internet Datagram Protocol. XNS level two is specified by the Echo Protocol, the Error Protocol, the Sequenced Packet Protocol, the Packet Exchange Protocol, and the Routing Information Protocol.

Bridge Communications and Network Research Corporation claim to fully implement the XNS level one and the XNS level two protocols for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system.

Interlan claim to fully implement the XNS level one and the XNS level two protocols, but they do not have an

Table III-3

XNS Level One Summary

XNS Level One	A	B	C	I	N
Internet Datagram Protocol	F	F	N	F	F

Definition of Symbols:

A = Advanced Computer Corporation
B = Bridge Communications
C = 3Com Corporation
I = Interlan
N = Network Research Corporation
F = Full Implementation
P = Partial Implementation
N = No Implementation

Currently. there is no device driver software for the Berkeley Unix 4.2 BSD operating system. However, by the time this report is release device driver software for the Berkeley Unix 4.2BSD operating system should be available.

Interlan and 3Com also have designed Ethernet controller boards for the VAX 11/780, but they do not have device driver software for the Berkeley Unix 4.2BSD operating system. However, the Berkeley Unix 4.2BSD networking facilities contain device driver software for the 3Com and the Interlan Ethernet controller boards. An interesting statement about the performance of the 3Com and the Interlan controller boards said they both have identical throughput characteristics with Berkeley Unix 4.2BSD, but neither have proven entirely satisfactory (31:12). The reasons being: 1) data has to moved between the VAX Unibus and the 3Com Ethernet controller board a word at a time and 2) the Interlan Ethernet controller board uses a significant amount of +5 volt power and it does not perform the Ethernet CRC checksum.

XNS Levels' One and Two. Level one of the XNS architecture structure contains the network layer function of the ISO model concerned with internetworking systems (See Table III-3). Level two of the XNS architecture structure contains the transport layer functions of the ISO model (See Table III-4). Specifications for XNS level one and XNS level two are outlined in the Internet Transport Protocols document (54).

area networking functions of the ISO model (See Table III-2). This research is interested in an XNS network environment with the Ethernet providing level zero service, because this is one of the requirements of the OSD P&FC office. The Ethernet Version 1.0 specification outlines the protocols for connecting to and establishing an Ethernet network (16).

Table III-2

XNS Level Zero Summary

XNS Level Zero	A	B	C	I	N
Ethernet Specification	F	F	F	F	F

Definition of Symbols:

A = Advanced Computer Corporation
B = Bridge Communications
C = 3Com Corporation
I = Interlan
N = Network Research Corporation
F = Full Implementation
P = Partial Implementation
N = No Implementation

Bridge Communications and Network Research Corporation have designed Ethernet controller boards and device drivers for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system.

Advanced Computer Communications (ACC) has also designed an Ethernet controller board for the VAX 11/780.

network server maintains the routing table used by internet routers by implementing a protocol similar to the XNS Routing Information Protocol.

Overview of Implemented Protocols

The OSD P&FC office requires the interfacing of a VAX 11/780 with Xerox office automation equipment. This interfacing would allow desired services between the VAX 11/780 and Xerox office automation equipment to occur such as electionic filing, mailing, and printing. The protocols that perform these services in a Xerox network environment are in level four of the XNS architecture structure. The XNS levels of protocols below XNS level four would also have to be implemented to meet the requirements of interfacing the VAX 11/780 with Xerox office automation equipment, because the protocols that compose the XNS architecture are layered.

A level by level discussion of which protocols of the XNS architecture structure have, or have not, been implemented for the VAX 11/780 is presented. This discussion is based on the information gathered from the Ethernet product line search, and the networking information presented on the Berkeley Unix 4.2BSD operating system.

The implementation of TCP/IP on the VAX 11/780 is also discussed, because this is another requirement of the OSD P&FC office.

XNS Level Zero. Level zero of the XNS architecture structure contains the physical, data link, and the local

the networking facilities' SOCK_STREAM socket type. The User Datagram Protocol (UDP) is a specification for a datagram delivery service. UDP uses the networking facilities' SOCK_DGRAM socket type to accomplish this task.

The Berkeley Unix 4.2BSD operating system also provides support for the DARPA application layer protocols SMTP, TELNET, and FTP (4). The Simple Mail Transfer Protocol (SMTP) provides an electronic mail service. The TELNET protocol provides a virtual terminal service. The File Transfer Protocol (FTP) performs electronic filing on an internet.

Ethernet and XNS Software Support. The Berkeley Unix 4.2BSD networking facilities contain software for connecting a VAX 11/780 to an Ethernet, and two network servers based on the XNS protocols.

The networking facilities contain hardware interface layer software for three 10Mb/s Ethernet controller boards. The three 10Mb/s Ethernet controller boards are the 3Com 3C300. the Interlan NI1010A, and the Proteon proNET (33:13-14).

The network facilities network servers that are based on XNS protocols are called "couried" and "routed" (34:34). The "couried" network server provides a remote procedure capability using the XNS Courier Protocol. The "routed"

information about a hardware device such as the hardware device name, the local network host number where the hardware device resides, and the network address of the interface routine to a hardware device. Delivery and reception of packets from a hardware device are managed by information in the hardware interface layer data structure such as a queue of packets to transmit and a queue of packets received from a hardware device. The hardware interface layer data structure also stores information pretaining to the hardware device network operations such as the number of packets received, the number of packets transmitted, the number of collision packets, the number of damaged packets sent, and the number of damaged packets received at a hardware device. Berkeley Unix 4.2BSD has a routine that takes the information stored in the hardware interface layer data structure about a hardware device's network operations and provides various statistics on the network operations of the hardware device.

DARPA Protocols Support. The Berkeley Unix 4.2BSD provides support for the DARPA standard Internet protocols IP, ICMP, TCP, and UDP (34:31). The Internet Protocol (IP) is a specification for the network layer functions of the ISO model. The Internet Control Message Protocol (ICMP) is the control protocol associated with IP that is used to convey error and status information to Internet users (5). The Transmission Control Protocol (TCP) is a specification for the transport layer functions of the ISO model that uses

manipulated by the user interface routines of the networking facilities (18:9).

The Communication Protocols Layer. The communication protocols layer manages the data structure that is associated with the use of a particular protocol (for example, the XNS Internet Datagram Protocol). The data structure that defines the use of a protocol contains four pieces of information; the protocol identification, protocol-to-protocol communications, user-to-protocol communications, and protocol utility routines (18:12). The protocol identification contains information such as the socket type that supports a protocol, the protocol identification number, and the protocol family (i.e XNS). The protocol-to-protocol communications data define those routines used to pass information to protocols above and below a given protocol. The user-to-protocol communications define the routine used to interface with the socket type a protocol is using. The protocol utility routines define the timing mechanisms used to determine the state of a protocol.

The Hardware Interface Layer. The hardware interface layer is responsible for encapsulation and deencapsulation of any low level header information required to deliver a message to its destination, in addition to manipulating a hardware device (18:13). The hardware interface layer manages the data structure associated with using a hardware device on a network system. The hardware interface layer data structure contains network addressing

concept of a reliable datagram service for the delivery of information. The SOCK_SEQPACKET socket provides a reliable sequential transmission of information. These socket types can be used to support the implementation of protocols that make up the network and transport layers of a network structure.

The Berkeley Unix 4.2BSD networking facilities have routines designed to assist in the manipulation of sockets (9:29-31). There are routines that allow the creation and naming of sockets. Routines exist that provide listening and answering services for sockets. Routines exist that establish connections between sockets. Routines exist that provide a means of sending and receiving information to/from sockets. Finally, routines exist to disconnect one or both sides of a connection between sockets.

Internal Structure. The internal structure of the networking facilities provided by Berkeley Unix 4.2BSD is outlined in the 4.2BSD Networking Implementation Notes document (18). This document specifies that the internal structure of the networking facilites are divided into three layers; the highest layer called the socket layer, the middle layer called the communication protocols layer, and the lowest layer called the hardware interface layer.

Socket Layer. The socket layer is composed of those data structures used to manage sockets and their interconnections. Most of the information stored in the socket management data structures are supplied and

The Berkeley Unix 4.2BSD operating system also contains implementations of the protocols that make up the Department of Defense (DOD) standard for internetworking as outlined by the Defense Advance Research Projects Agency (DARPA). The DOD internetworking protocols were implemented using the networking facilites of the Berkeley Unix 4.2BSD operating system.

Berkeley Unix 4.2BSD also contains software implementations related to connecting a VAX 11/780 to an Ethernet, as well as protocols related to the XNS architecture structure.

User Interface. The user interface provided by the Berkeley Unix 4.2BSD networking facilities is centered on the concept of a socket. A socket is a bidirectional endpoint of communications which is "typed" by the semantics of the communications it supports (18:8). Sockets are the means by which information is exchanged between processes in a network environment. Currently, Berkeley Unix 4.2BSD networking facilities define five socket types; they are SOCK_DGRAM, SOCK_STREAM, SOCK_RAW, SOCK_RDM, and SOCK_SEQPACKET (9:28). The SOCK_DGRAM socket uses the concept of a datagram delivery of information. The SOCK_STREAM socket uses the concept of a virtual circuit for the delivery of information. The SOCK_RAW socket allows direct access to the network layer functions without a scheme at the transport layer to ensure the reliable transmission of information. The SOCK_RDM socket uses the

Ethernet product line, and 3) Ethernet product lines specify interfacing of other systems with XNS networks, thereby revealing possible future additions of other systems to the OSD P&FC network. The Ethernet product line literature search information is located in Appendix A.

The literature search on the networking facilities of the Berkeley Unix 4.2BSD operating system is in four areas: 1) the networking facilities of the Berkeley Unix 4.2BSD operating system, 2) any sofware support for TCP/IP, 3) any software support for the Ethernet, and 4) any implementations of the XNS protocols.

This chapter then presents an overview of the implemented XNS and TCP/IP protocols.

The chapter concludes with a summary of the XNS and the TCP/IP protocols that have, or have not, been designed and implemented on the VAX 11/780 with Berkeley Unix 4.2BSD.

Berkeley Unix 4.2BSD Operating System

The XNS protocol structure that must be designed for the VAX 11/780 to enable it to interface with Xerox networking devices at the application layer will be under the Berkeley Unix 4.2BSD operating system, as required by the OSD P&FC office. The Berkeley Unix 4.2BSD operating system defines a framework for supporting network applications. The networking facilities available under Berkeley Unix 4.2BSD have a user interface and a documented internal structure to assist network designers in the design and implementation of network systems.

Table III-1

XNS Architecture Structure

Level Four (Application Layer)
Filing Protocol Mailing Protocol Printing Protocol Other Applications Support Protocols
Level Three (Presentation and Session Layers)
Courier Protocol Bulk Data Transfer Protocol
Level Two (Transport Layer)
Sequenced Packet Protocol Echo Protocol Packet Exchange Protocol Error Protocol Routing Information Protocol
Level One (Network Layer)
Internet Datagram Protocol
Level Zero (Data Link and Physical Layers)
Ethernet Specification

III. Protocols Implementation Status

Introduction

As outlined in the previous chapter, a layered architecture structure is required for networking with Xerox Network Systems. All five levels of the Xerox Network System (XNS) protocols must be developed on the VAX 11/780 to meet the requirements specified by the Office of the Secretary of Defense (OSD) Program and Financial Control (P&FC) office (See Table III-1). The requirements specified by the Program and Financial Control office involves the interfacing of the VAX 11/780 with Xerox office automation equipment at the application layer.

A literature search was performed to determine which communications protocols of XNS have already been designed and implemented for the VAX 11/780 with the Berkely Unix 4.2BSD operating system, the system the OSD P&FC office is acquiring. The results of the literature search is composed of two parts: 1) information on Ethernet specific product lines, and 2) information on the networking facilities of the Berkeley Unix 4.2BSD operating system.

A literature search of Ethernet product lines is performed for three reasons: 1) the OSD P&FC office has an Ethernet at level zero of their Xerox network environment, 2) most implementations of the XNS protocols are part of an

research was also performed to determine the extent that TCP/IP was implemented on the VAX 11/780.

The next chapter reviews information gathered during a literature search that was performed to determine which protocols of the Xerox Network System and TCP/IP have already been implemented for the VAX 11/780 using the Berkeley Unix 4.2BSD operating system.

implementation for the Berkeley Unix 4.2BSD operating system. However, they point out that their implementation is in the C programming language. This should make it easier to transport their implementation to systems with the C programming language, such as the VAX 11/780 with the Berkeley Unix 4.2BSD operating system.

ACC has a full implementation of the XNS level one protocol. They also have a partial implementation of the XNS level two protocols. ACC does not have a full implementation of the Routing Information Protocol and the Error Protocol, which are part of the XNS level two protocols. They also have not implemented the Packet Exchange Protocol, another XNS level two protocol. ACC's implementations of the XNS level one and the XNS level two protocols should be available for the Berkeley Unix 4.2BSD operating system, by the time this report is released.

XNS Level Three. Level three of the XNS architecture structure contains the session layer and the presentation layer functions of the ISO model (See Table III-5). Specifications for XNS level three are outlined by the XNS Courier Protocol (55) and the XNS Bulk Data Transfer Protocol (56).

ACC has a partial implementation of the XNS level three protocols, with a full implementation of the Courier Protocol and no implementation of the Bulk Data Transfer Protocol. Currently, their implementation of XNS level three is only for Unix V7 operating systems. However, they

should have an implementation for the Berkeley Unix 4.2BSD operating system by the time this report is released.

Table III-5

XNS Level Three Summary

XNS Level Three	A	B	C	I	N
Courier Protocol	F	N	N	N	N
Bulk Data Transfer Protocol	N	N	N	N	N

Definition of Symbols:

A = Advanced Computer Corporation
B = Bridge Communications
C = 3Com Corporation
I = Interlan
N = Network Research Corporation
F = Full Implementation
P = Partial Implementation
N = No Implementation

Berkeley Unix 4.2BSD has a partial implementation of the XNS level three protocols, with a full implementation of the Courier Protocol and no implementation of the Bulk Data Transfer Protocol. The Courier Protocol implemented as part of the Berkeley Unix 4.2BSD networking facilities is offered as a network server. However, the Berkeley Unix 4.2BSD networking facilities do not implement XNS level one and XNS level two in support of the Courier Protocol network server.

XNS Level Four. Level four of the XNS architecture structure contains the protocols and standards found in the

application layer of the ISO model (See Table III-6). The major application services of the XNS architecture structure are electronic filing, printing, and mailing. These are the same application services the OSD P&FC office would like the VAX 11/780 to interface with their Xerox network. Each major application service is composed of protocols and standards for implementing the service. The XNS level four also has application services such as a service for locating devices and other application services on a network, and a service for verifying user access to devices and application services on a network.

Table III-6

XNS Level Four Summary

XNS Level Four	A	B	C	I	N
Filing Protocol	P	N	N	N	N
Mailing Protocol	N	N	N	N	N
Printing Protocol	N	N	N	N	N
Other Applications	N	N	N	N	N
Support Protocols	P	N	N	N	N

Definition of Symbols:

A = Advanced Computer Corporation
B = Bridge Communications
C = 3Com Corporation
I = Interlan
N = Network Research Corporation
F = Full Implementation
P = Partial Implementation
N = No Implementation

An effort was made to acquire the protocols and standards of the electronic filing service. This was done for two reasons: 1) this is one of the services the OSD P&FC would like a VAX 11/780 to perform with Xerox network devices and 2) the electronic filing service is the basis for transmitting information in a network environment. Xerox, however, has decided that their electronic filing service protocols and standards are still in a period of evolution and are not stable enough for release to the public. The only major application service released to the public by Xerox is their electronic printing service.

The Xerox electronic printing service was released to the public in a package called Interpress. The Interpress package contains the protocols and standards of the Xerox electronic printing service, other application layer protocols and standards used by the electronic printing service, and all the protocols of the XNS levels' one through three. The protocols and standards of the electronic printing service are in these documents: the Interpress 82 Reader's Guide (52), the Introduction to Interpress (BY), the Interpress Electronic Printing Standard (57), the Character Code Standard (58), and the Printing Protocol (62). The other application layer protocols and standards used by the electronic printing service are the Time Protocol (60), the Authentication Protocol (61), the Clearinghouse Entry Formats (63), and the Clearinghouse Protocol (59).

ACC has a partial implementation of the Clearinghouse Protocol. They have used this implementation, along with the other XNS protocols they have implemented, to design their own electronic filing service (2). In fact, Xerox has asked them to develop an interpretor which is to be used for file transfers between the Xerox file service and the ACC file service.

TCP/IP Requirement. The OSD P&FC office has as a requirement the use of the DARPA TCP/IP protocols at the network and transport layers of the ISO model. 3Com has implemented TCP/IP on the VAX 11/780. They also have a partial implementation of the DARPA protocols for file transfer, virtual terminal service, and electronic mailing. However, the Berkeley Unix 4.2BSD networking facilities have a full implementation of the DARPA protocols TCP, IP, UDP, and ICMP. The Berkeley Unix 4.2BSD networking facilities also provides support for the DARPA application layer protocols FTP, SMTP, and TELNET.

Summary

The literature review performed reveals that XNS levels' zero through two are implemented for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system. It also reveals that Berkeley Unix 4.2BSD has a full implementation of TCP/IP, along with the UDP, ICMP, FTP, SMTP, and the TELNET DARPA protocols.

The literature review also reveals that there are not

full implementations of XNS level three and the electronic filing protocol of XNS level four. The electronic filing protocol uses XNS level three, hence a full implementation of XNS level three is required. The only protocol of XNS level three that has not been implemented is the Xerox Bulk Data Transfer Protocol. Therefore, the next chapter presents a general design of the Xerox Bulk Data Transfer Protocol.

IV. General Design of A XNS Protocol

Introduction

The full range of XNS protocols that support and provide the electronic filing, printing, and mailing services on a Xerox Network System have not been implemented for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system. However, some of the protocols that make up the XNS network structure have been designed and implemented for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system, as outlined in the previous chapter (See Tables III-2 thru III-6). The XNS architecture structure is layered, therefore it requires the lower levels of the XNS structure to exist before higher levels, such as electronic filing, printing, and mailing, can be implemented.

The previous chapter pointed out that the protocols which compose the XNS levels zero through two have been, or will soon be, designed and implemented for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system. It was also pointed out that the Advanced Research Corporation (ACC) had a partial implementation of the XNS level three protocols. Level three of the XNS architecture structure is composed of two protocols, the Courier Protocol (55) and the Bulk Data Transfer Protocol (56). ACC has a full implementation of the Courier Protocol, but no implementation of the Bulk Data Transfer Protocol.

Level four of the XNS structure, that includes electronic filing, printing, and mailing functions, are dependent directly on the use of the Courier Protocol and the Bulk Data Transfer Protocol of XNS level three. Therefore, a design and an implementation of the Bulk Data Transfer Protocol for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system is required, if XNS level four applications are to be implemented as desired by the Program and Financial Control office.

This chapter begins with a brief overview of the Courier Protocol, because it is the means by which communications is specified by the Bulk Data Transfer Protocol. Also, an overview is presented on the Xerox Bulk Data Transfer Protocol. Finally, a general design of the Xerox Bulk Data Transfer is discussed.

The Courier Protocol

The Xerox Courier Protocol provides session and presentation support, as outlined by the ISO model, for application protocols on a Xerox network. The Courier Protocol provides this support through the use of remote procedure calls. Remote procedure calls allow network users to execute programs located on remote host systems on a Xerox Network System. The Courier Protocol facilitates the construction of distributed systems by defining a single request/reply or transaction discipline for an open-ended set of higher-level applications protocols (55:1).

Courier is designed to assist developers of network services. A network service designer can view a network service as a program that can be accessed by any remote host system on a Xerox Network System. The network service program is composed of procedures that perform primitive functions of a network service. This is analogous to a program developed in a high level language that is composed of subprograms which perform functional tasks.

For example, an electronic printing network service program might be composed of procedures that spool a file to a printer, delete a file from a spooled printer queue, and change the priority of files waiting to be printed in a spooled printer queue. The electronic printing network service is advertised as a complete service. A print service request is carried out for a user of a network by issuing the appropriate remote procedure calls to the electronic printing program located at a remote printer.

The Courier Protocol is composed of three layers, the block stream, the object stream, and the message stream (See Figure IV-1). The block stream layer defines how the Courier message and data stream is demarcated and transmitted between established sockets on a Xerox Network System. The object stream layer defines the data types that Courier support. Some of the data types Courier support are cardinal, string, integer, array, and record. The message stream defines the message types that can be used for communication between requestors and providers of services on a Xerox Network System.

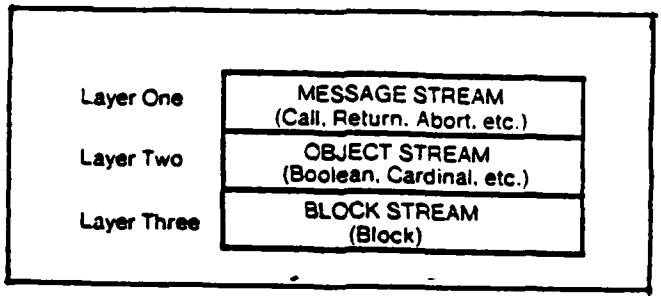

Figure IV-1. The Courier Layered Structure

Source: 55:3

Courier, like the XNS architecture structure, has a layered structure where the higher layers depend on the lower layers. Courier layer three (the message stream) uses the constructs provided by Courier layer two (the object stream) to create calls to and interpret returns from remote procedures. Courier layer one (the block stream) ensures that Courier layer two (object stream) information is transmitted between host systems on a Xerox Network System. The Courier Protocol uses the Xerox Sequenced Packet Protocol (54) for the reliable transmission of block stream data.

Since, ACC has already implemented the Courier Protocol, the detail specification of the object stream and the block stream layers are not discussed. A detailed discussion of the object stream and the block stream would be needed if a design and an implementation of Courier were being presented. However, what is discussed in detail is Courier layer three, the message stream.

Courier defines four message types: the call message,

the reject message, the return message, and the abort message (55:23). Requestors of network services uses the call message to initiate the execution of remote procedures on a Xerox Network System (See Figure IV-2). The response to issuing a call to a remote procedure is returned by either a reject message, a return message, or an abort message. The Courier Protocol specifies that a user process can only have one call message outstanding at any given time (55:24).

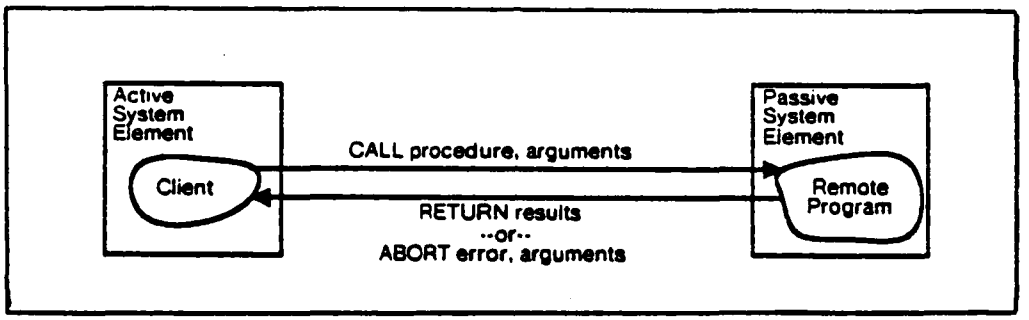

Figure IV-2. The Courier Model

Source: 55:2

The call message has a structure that is composed of a program number. a version number, a procedure value, and procedure arguments. The program number specifies the network service program a requestor wants to execute. The version number specifes the version of a network service program a requestor wants to execute. The procedure value specifies the procedure of the network service program a requestor wants to execute. The procedure arguments specify the arguments a requestor is supplying to the procedure of

the network service program. All of the procedure arguments passed to a remote procedure must use the data typing specified for the remote procedure by the network service program.

The reject message is used by a network service program to denote that a call to a remote procedure was rejected. The return of a reject message from a network service program means the execution of a remote procedure was not attempted. The reject message specifies five standard reasons why a call to a remote procedure was rejected (55:25-26):

1. A program number specified by a call message does not designate an existing network service program.

2. A version number specified by a call message is not implemented by a network service program. If this reject message is returned, the network service program also returns to the caller of a remote procedure the lowest and the highest version of the network service program it supports.

3. A call message sent to a network service program specified a procedure not supported by the network service program.

4. A call message does not have the expected procedure arguments for a remote procedure.

5. For reasons other than the ones discussed above which prevent a network service program from initiating the execution one of its procedures.

The return message specifies the results from executing a remote procedure call. A return message is sent only when a remote procedure executes successfully. The results returned by a remote procedure are outlined by a network service program. just as the procedure arguments to a remote procedure are outlined by a network service program. The results returned by a remote procedure are data typed using the formats specified by Courier layer two, the object stream.

The abort message is returned when an error occured during the execution of a remote procedure. The network service program defines appropriate error conditions for each procedure that composes a network service program. Each error condition is given a numeric error value, which is used to signal the occurrence of a particular error. Therefore, the abort message returns an error value that is used to decoded the error condition that occurred during the execution of a remote procedure. The abort message may in addition to returning an error value, also return parameters. These parameters are usually the procedure

arguments passed to a remote procedure, via a call message, that caused the generation of an abort message.

Xerox Bulk Data Transfer Protocol

The Xerox Bulk Data Transfer Protocol is the means by which application services on a Xerox Network System, such as file service and print service, transfer large amounts of information. The Xerox Bulk Data Transfer Protocol standardizes the mannner in which the sender and receiver of bulk data make contact with one another; how bulk data is demarcated when transfered on the Courier connection between them; and how the transfer can be aborted; if necessary by either party (56:35).

This protocol is an extension of the Courier Protocol. The Courier Protocol is designed for calling and receiving status messages, or return arguments, from remote procedures. In other words, it is designed only for initiating a network service, such as electronic filing or printing. The Courier Protocol is not designed for the transfer of the actual bulk data that an electronic filing or printing network service requires. Xerox has specified how this task is performed between system elements on a Xerox Network System in the Xerox Bulk Data Transfer Protocol.

Like the Courier Protocol, the Xerox Bulk Data Transfer Protocol is designed to assists designers of network services. The Bulk Data Transfer Protocol assisc designers

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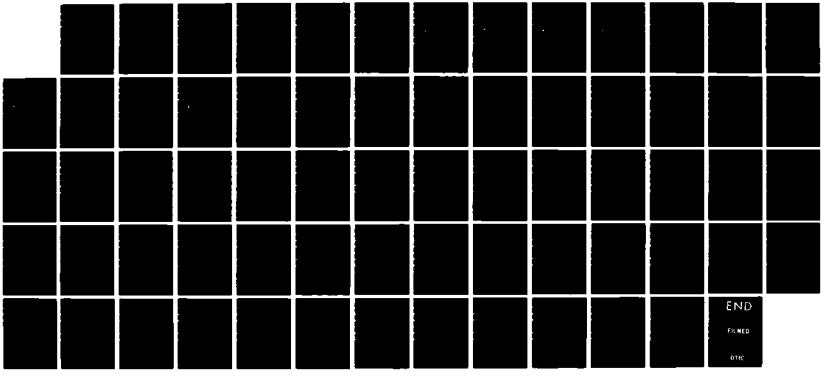
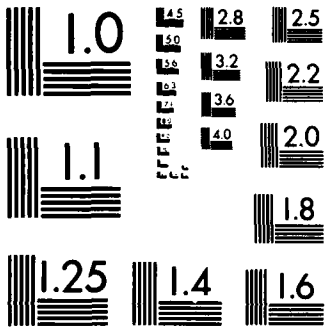
UNCLASSIFIED DEC 84 AFIT/GCS/ENG/84D-4-VOL-1 F/G 9/2 NL





of network services by providing a standard dialogue between system elements on a network that participate in the transfer of bulk data. The Xerox Bulk Data Transfer Protocol views the transfer of bulk data requires communication between three system elements: the initiator, the sender, and the receiver.

The initiator receives and acts upon a request for the transfer of bulk data. For example, a user on a workstation requesting a file be sent to a print server would be serviced by an initiator. The sender sends bulk data requested to a specified destination. For example, a file service sending a file to a designated print service. The receiver accepts bulk data sent to it and acts upon it. For example, a print service receiving bulk data from a file server that is to be printed.

Depending on where the initiator, the sender, and the receiver of bulk data is located on a network, and the bulk data request itself, determines the type of bulk data transfer required. The Bulk Data Transfer Protocol supports three forms of bulk data transfers: third-party, immediate, and null (56:36). A third-party transfer is performed when the bulk data to be transmitted is not located at the initiator host system, and it is not destined to be sent to the initiator host system. Therefore, the communications required to transmit the bulk data is between three host systems, the initiator host, the sender host, and the receiver host.

An immediate transfer is performed when the bulk data to be transmitted is either located at, or destined to be sent to the host system that received a request for a bulk data transfer (i.e. the initiator host system). The communications required to transfer the bulk data is between two host systems, the initiator host system and either the sender host or the receiver host.

A null transfer is performed when a bulk data request requires that no data is actually sent. For instance, a request to create an empty file on a file service device. The communcations for this type of bulk data transfer is between two host systems, the initiator host and either the sender host or the receiver host.

The communications between the initiator, the sender, and the receiver is carried out mainly through the use of Courier remote procedure calls. The initiator determines the type of bulk data transfer that is needed for each bulk data request it receives, and issues the appropriate remote procedure call(s) to the sender and/or the receiver. The sender has a remote procedure called Produce, which retrieves the bulk data requested at a system element and transmits it to another system element as designated by the initiator. The receiver has a remote procedure called Consume, which accepts bulk data from a system element designated by the initiator.

The Produce and Consume remote procedures are not generalized procedures that can be used for all bulk data

transfers. These two remote procedures are application specific for each network service application, just as the application specific initiator of a network service is. The Xerox Bulk Data Transfer Protocol outlines the functions the initiator of a network service, and the application specific remote procedures, Produce and Consume, must perfom to ensure a standard and orderly exchange of bulk data.

General Design of the Xerox Bulk Data Protocol

The previous section gave the motivation for the use of the Xerox Bulk Data Transfer Protocol, that being to assist network designers in the transfer of bulk data between system elements on a network system. This is achieved by outlining communication standards between system elements that participate in the transfer of bulk data. This section concentrates on a general design of the Xerox Bulk Data Protocol. The general design maps out the communications among the initiator of a bulk data request, the Produce remote procedure, and the Consume remote procedure.

The general design of the Xerox Bulk Data Transfer Protocol requires the use of a technique that can represent the communications among the initiator of a bulk data request, the Produce remote procedure, and the Consume remote procedure. The Structured Analysis and Design Technique (SADT) (15, 48, 50), Data Flow Diagrams (44:139), and the Hierarchy Plus Input Process Output (HIPO) (44:48) technique are all techniques that can be used to represent the relationships between components of a system.

The general design of the Xerox Bulk Data Transfer Protocol is presented using the Structured Analysis and Design Technique. This general design technique was chosen for three reasons: 1) it provides a top down design structure, 2) it represents the design graphically, while highlighting the components of a design, and 3) it shows the relationships between objects and activities of a system (44:134).

The general design presented can be used as a blueprint for implementing support for bulk data transfers required by application services on a Xerox Network System. The full Bulk Data Transfer Protocol must exist on each host system on a Xerox network that can initiate, produce, and consume an application service's bulk data.

Host systems on a Xerox network that only retrieve an application service's bulk data at the local host system, and sends it to a designated host system on the network, need only implement the Produce remote procedure of the Bulk Data Transfer Protocol.

Host systems on a Xerox network that only accept bulk data sent to it, need only implement the Consume remote procedure of the Bulk Data Transfer Protocol.

Host systems on a network that can produce and consume, but not initiate, an application service's bulk data must implement the Produce and the Consume remote procedures of the Bulk Data Transfer Protocol.

An application service uses its application specific

Bulk Data Transfer Protocol for the transmission of information that require a bulk data transfer. The application specific Bulk Data Transfer Protocol can be viewed as a complete system, where a bulk data request is input to the system, and the result of the bulk data request is the output of the system (See Figure IV-3). The heart of the Bulk Data Transfer Protocol is the communications and data transfers among the initiator of a bulk data request, the Produce remote procedure, and the Consume remote procedure (See Figure IV-4).

The Initiator. The initiator receives a request for performing a bulk data transfer (See Figure IV-5). The bulk data request must be parsed to extract information such as the name, the request type, and the destination of the bulk data (See Figure IV-5 SADT A11). This information is used to find the source and the sink (destination) addresses of the host systems that will participate in the bulk data transfer (See Figure IV-5 SADT A12 and SADT A13). The initiator address, the source address, the sink address, the request type, and the bulk data name are used to initiate the appropriate type of transfer needed to transmit the bulk data (See Figure IV-5 SADT A14).

The type of bulk data transfer used depends on where the bulk data is located, where it is destined, and the request type of the bulk data request (See Figure IV-6 SADT A141). A null bulk data transfer is used when a bulk data

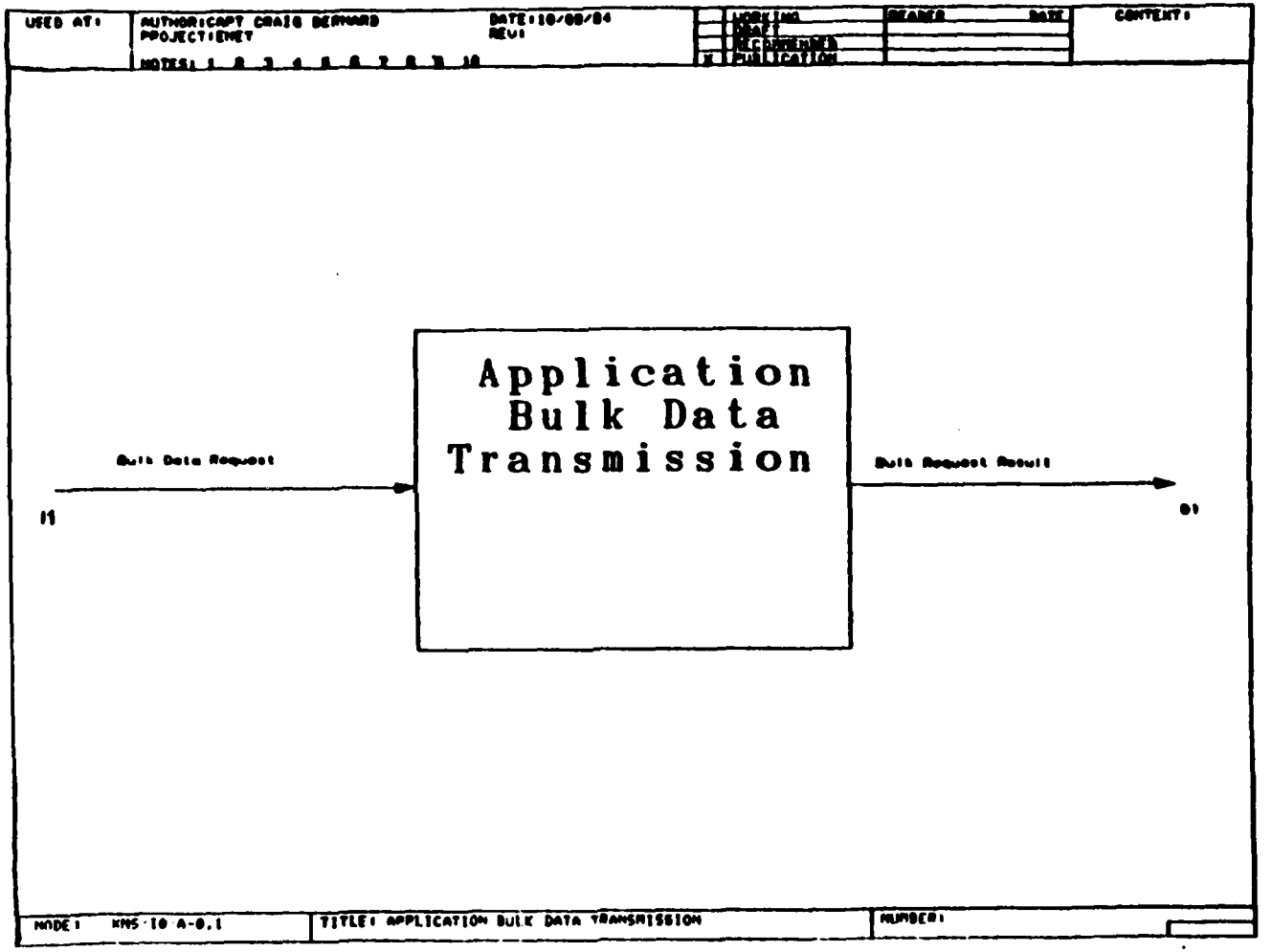


Figure IV-3. SADT A-0

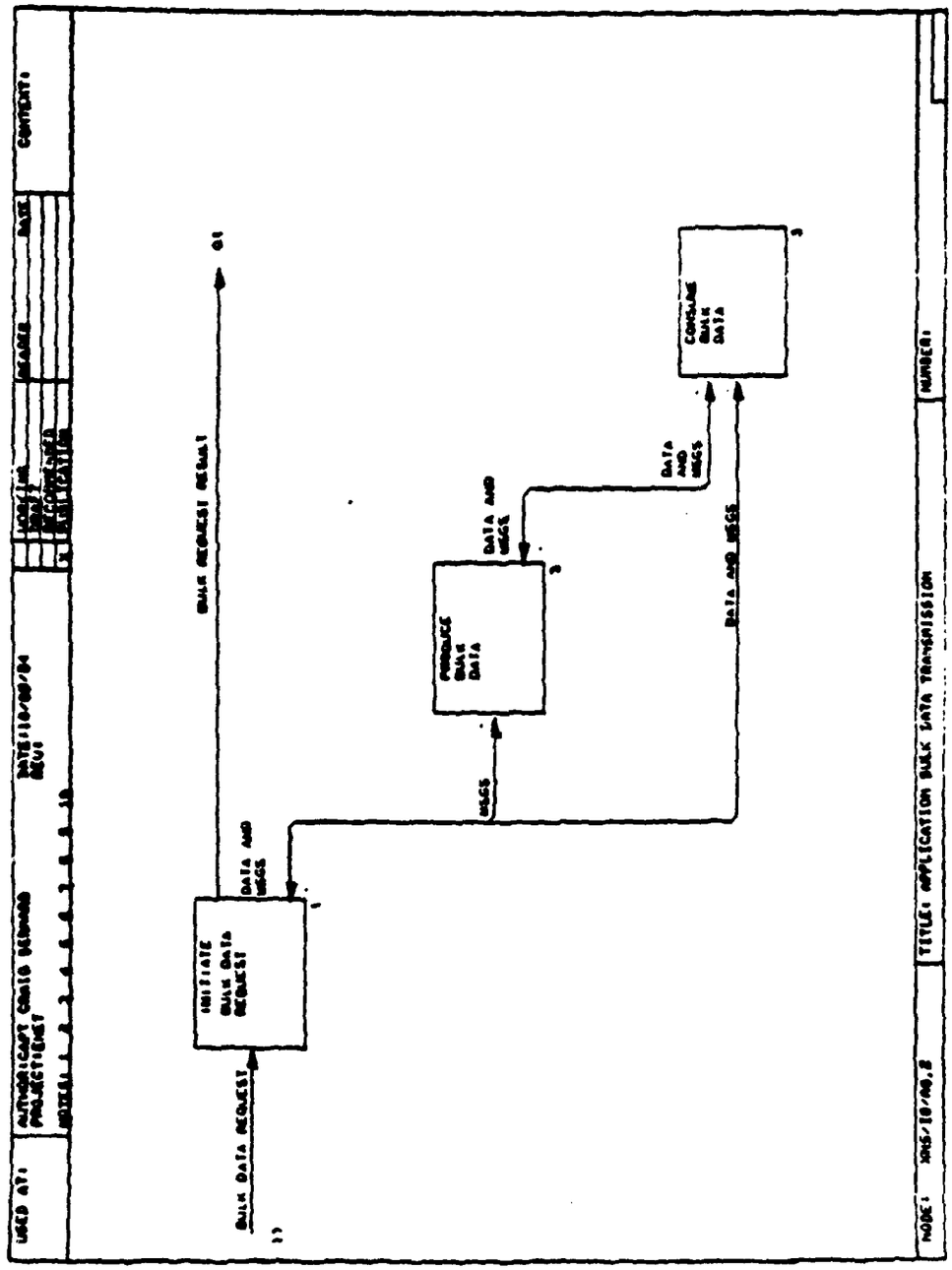


Figure IV-4. SADT A0

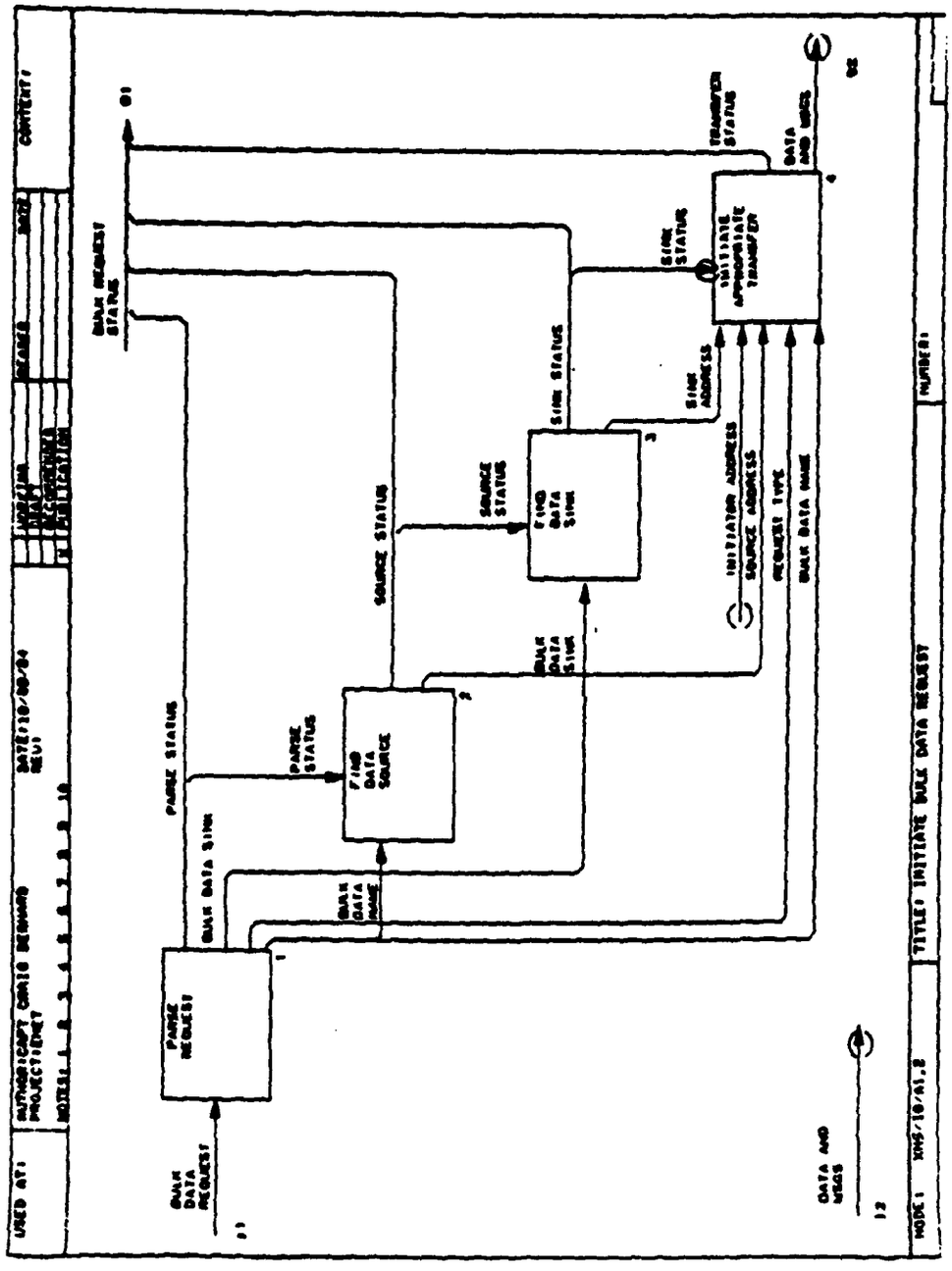


Figure IV-5. SADT A1

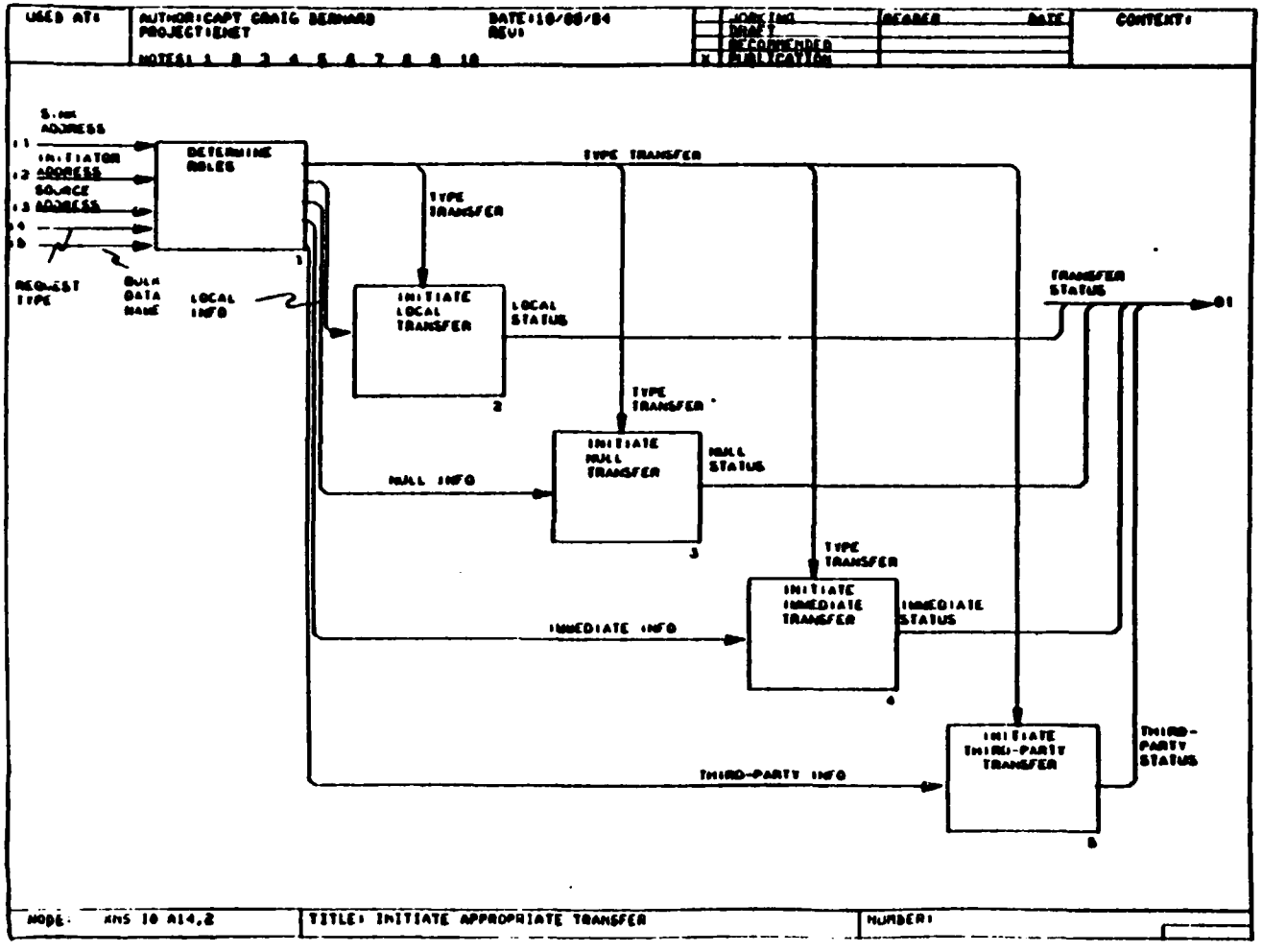


Figure IV-6. SADT A14

request type specifies the creation or emptying of a file, and the bulk data is not located at the initiator address (See Appendix B SADT A143). An immediate bulk data transfer is used when the source address or the sink address of the bulk data is the same as the initiator address (See Figure IV-6 SADT A144). A third-party bulk data transfer is used when neither the source address nor the sink address is the same as the initiator address (See Figure IV-6 SADT A145). A local bulk data transfer is used when the source address and the sink address of the bulk data is the same as the initiator address (See Figure IV-6 SADT A142).

The Xerox Bulk Data Transfer does not address the issue of the local transfer of bulk data. It probably does not address this issue because only one system element is involved, that system being the host system where the bulk data request was received. Therefore, there is no requirement for communication between system elements of an application service to achieve the data transfer. The bulk data transfer takes place using an application service procedure at the local host system, without the need to use a Courier connection for communication and data transfer.

However, in the case of the null, immediate, and third-party bulk data transfers, a Courier connection is used for communication and the transfer of bulk data among the initiator, the Produce remote procedure, and the Consume remote procedure. Once the type of bulk data transfer is determined, communcation between the initiator, and the

appropriate Produce and/or Consume remote procedures, is carried out. This communication specifies the role(s) the initiator has assigned to the Produce and/or Consume remote procedures in order to accomplish a bulk data request.

The initiator can assign one of four roles to the Produce and the Consume remote procedures: null, immediate, passive, and active. The null role specifies that the remote procedure is to participate in a null transfer of bulk data. The immediate role specifies that the remote procedure is to participate in an immediate transfer of bulk data. The active or passive role specifies that the remote procedure is to participate in a third-party transfer of bulk data. The Produce and the Consume remote procedures must honor all four roles an initiator can assign to them, if they are to comply with the Bulk Data Transfer Protocol (56:41).

Null Transfer. A null role is assigned to a Produce remote procedure when it is decided that a null transfer is to be used, and the bulk data request is for a task such as creating a file (See Appendix B SADT A1431). A null role is assigned to a Consume remote procedure when it is decided that a null transfer is to be used, and the bulk data request is for a task such as emptying a file (See Appendix B SADT A1432).

Immediate Transfer. An immediate role is assigned to a Produce remote procedure when it is decided that an immediate transfer is to be used, and the destination of the

bulk data is the initiator address (See Appendix B SADT A1441). An immediate role is assigned to a Consume remote procedure when it is decided that an immediate transfer is to be used, and the destination of the bulk data is not the initiator address (See Appendix B SADT A1442).

Third-Party Transfer. The initiator calls both the Produce and the Consume remote procedures simultaneously when a third-party transfer is used to transmit bulk data (See Appendix B SADT A145). The source address of a third-party transfer is used to call the Produce remote procedure. The sink address of a third-party transfer is used to call the Consume remote procedure. The initiator decides the complimentary passive or active roles that the Produce and the Consume remote procedures are to perform.

The Produce Remote Procedure. The Produce remote procedure communicates with two system elements. It directly communicates directly with the initiator, and indirectly with the Consume remote procedure (See Figure IV-4). The initiator activates the Produce remote procedure supplying arguments. The main argument supplied defines the role Produce is to play in a bulk data transfer (See Figure IV-7 SADT A2). The bulk data located at the Produce host system is retrieved, when Produce is to participate in an immediate or third-party transfer (See Figure IV-7 SADT A21). The Produce remote procedure returns the status of performing its assigned role via the initiator Courier connection.

bulk data. The first process, called SendData (See Appendix E-55), sends bulk data on a connection established by a Courier call message. The second process, called AcceptData (See Appendix E-2), receives bulk data from a connection established by a Courier call message. These two processes are not only used by the initiator system, but also the Produce remote procedure system, the Consume remote procedure system, and the Bulk Data system.

The Produce and The Consume Systems. The Produce and the Consume remote procedures transfer bulk data either with each other, or with the initiator. The roles the initiator assigns to the Produce and the Consume remote procedures determine the source and the destination systems in a bulk data transfer. The initiator communicates these roles along with other arguments, to the Produce and the Consume remote procedures via its interface with the Produce and the Consume server programs (43:3-1).

A detailed design process, called ProduceServer (See Appendix E-44), performs the function of interfacing with the initiator on behalf of the Produce remote procedure. A detailed design process, called ConsumeServer (See Appendix E-45), performs the function of interfacing with the initiator on behalf of the Consume remote procedure. The ProduceServer and the ConsumeServer processes decapsulate Courier data typed (55:8) arguments sent to the Produce and the Consume remote procedures by Courier call messages. After the arguments are decapsulated into the data types

only difference being a detailed design process used to clarify how the initiator's host address is generated, while in the SADT general design reflects the need for the information. The lower level processes that complete the detailed design of the initiator also parallel the lower level activities specified in the SADT general design of the initiator.

The SADT general design of the initiator's communications with the Produce and the Consume remote procedures is specified by a number of activities (See Appendix B, SADTs, A14311, A14312, A14322, A14411, A14413, A14422. A1452. A1453, and A1455). The detailed design of the initiator produced two common processes that is used for communications with the Produce and the Consume remote procedures. The first process, called SendConnectMsg (See Appendix E-54), is used to send remote procedure calls to the Produce and the Consume remote procedures. The second process, call RecStatusMsg (See Appendix E-47), is used to receive the response from a remote procedure call to the Produce and the Consume remote procedures.

The transmission of the bulk data between system elements is carried out by the use of the Xerox Sequenced Packet Protocol. The SADT general design of the transmission of bulk data specifies a number of activities (See Appendix B, SADTs A14412, A14423, A23, A2412, A2422, A32. A3312. and A3322). The detailed design of the initiator uses two processes for transferring and receiving

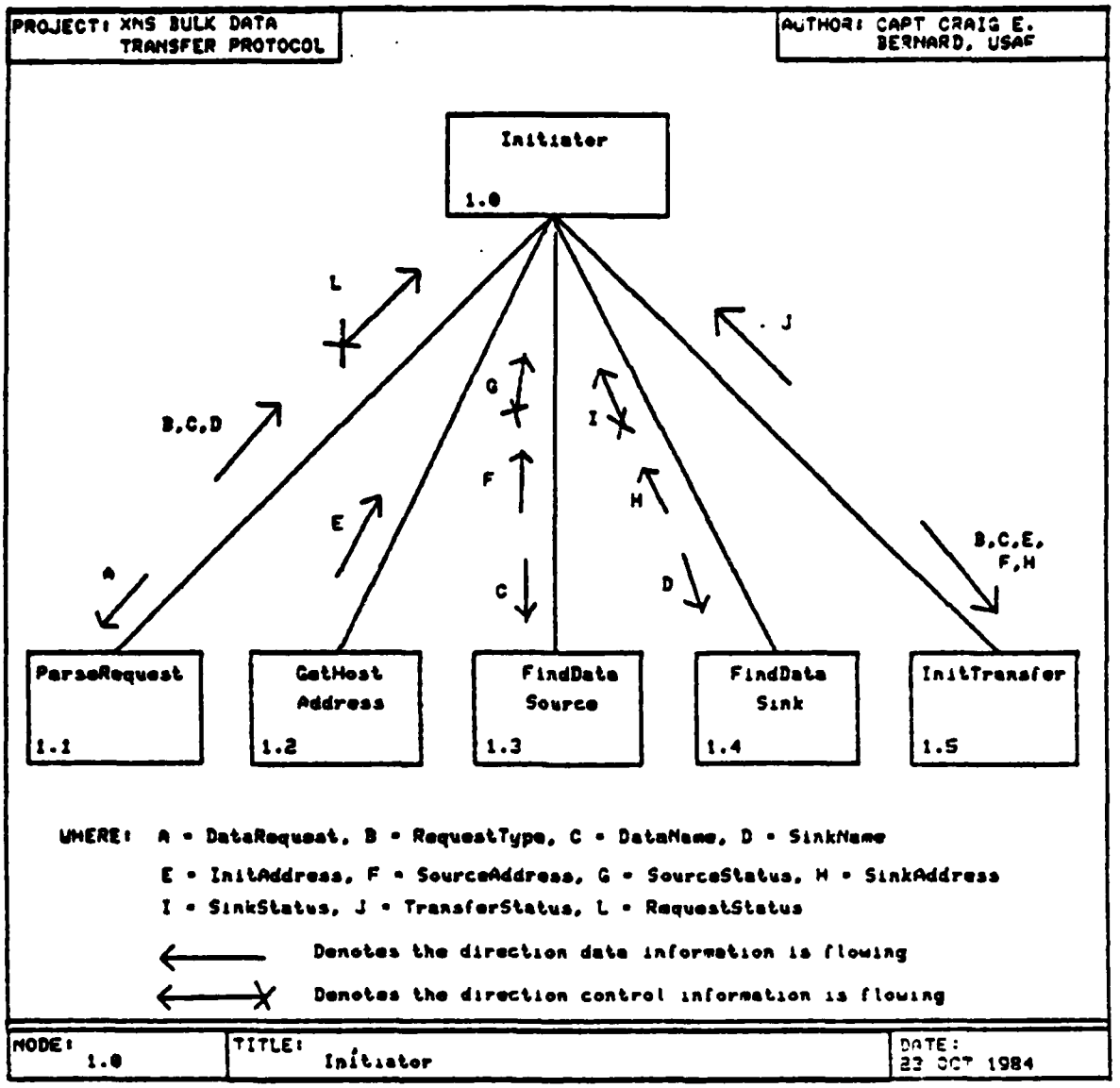


Figure V-1. The Initiator Process

Send, the Receive, and the Cancel remote procedures. This new system is referred to as the Bulk Data system, during the rest of this chapter.

The detailed design of the Send, the Receive, and the Cancel remote procedures can be carried out through the use of the structure charts technique (44:60), the Jackson method (44:153), or the Warnier mechanics method (44:159). The detailed design of each of these systems are presented using the structure charts (8, 64) design tool. Structure charts are used because of its top down decomposition of requirements specifications, such as SADT diagrams. Structure charts are also used because its black box approach to decomposition of high level requirements frees the designer from having to worry about minute details (44:61). This leads to detailed designs that can be used to implement code in any high level language.

The Initiator System. The initiator controls the actions performed during a transfer of bulk data, as pointed out in the SADT general design. The initiator controls the transfer of bulk data between the host system that has the bulk data, and the host system where the bulk data is destined. The main processes (See Figure V-1) that compose the top level detailed design of the initiator are modeled after the top level activities outlined in the SADT general design of the initiator (See Appendix B-9). The

Implementation

As mentioned earlier, an implementation is presented for the Xerox Bulk Data Transfer Protocol. The implementation is based on the SADT general design of the Xerox Bulk Data Transfer Protocol. The implementation is composed of two parts. The first part of the implementation is a detailed design of the SADT general design. The second part of the implementation is the code derived from implementing the detailed design in a high level programming language on a particular host system.

Detailed Design Implementation. The SADT general design presented in chapter four was used to implement a detailed design of the Xerox Bulk Data Transfer Protocol. The detailed design specfies how the initiator, the Produce remote procedure, and the Consume remote procedure perform the activities specified for them in the SADT general design. The detailed design also outlines in greater detail how the communciations among the initiator, the Produce remote procedure, and the Consume remote procedure are carried out. An indepth design of the Send, the Receive, and the Cancel remote procedures that are used to transfer third-party bulk data is also presented.

The detailed design, like the SADT general design, has three major systems: the initiator, the Produce remote procedure, and the Consume remote procedure. In addition to these three systems, the detailed design has formally recognized one more system. This system is composed of the

Still another bulk data service might support Clearinghouse service applications (59). The communcations required to transfer bulk data between host systems in each of these application services are the same, that being the communciations outlined in the Xerox Bulk Data Transfer Protocol. However, the data typing of the bulk data being transferred, and the operations that can be performed on the bulk data are application specific.

This chapter presents an implementation of the Xerox Bulk Data Transfer Protocol. The implementation is based on the SADT general design of the Xerox Bulk Data Transfer Protocol (See Appendix B). The emphasis of this implementation is on the communications required to transfer bulk data between host systems on a network. This implementation does not address such issues as how the bulk data is retrieved from a host file system, or the types of operations that can be performed on the bulk data, such as copying, renaming, or merging of the bulk data. These types of issues are addressed in a given application service's implementation of a bulk data service.

This chapter also outlines the test procedures used to test the implementation of the Xerox Bulk Data Transfer Protocol. The types of test procedures used to test the implementation of the Xerox Bulk Data Transfer Protocol fall into two categories, static testing and dynamic testing.

V. Implementation and Testing of the Xerox Bulk Data Transfer Protocol

Introduction

The Xerox Bulk Data Transfer Protocol provides communications standards for the transmission of bulk data between host systems on a network. The previous chapter outlined the main structure of this protocol, that being the communications among the initiator, the producer, and the consumer of a bulk data request. The Xerox Bulk Data Transfer Protocol specifies that the communications among these three system entities are accomplished by the use of the remote procedure call facility of the Xerox Courier Protocol (55). The Xerox Bulk Data Transfer Protocol also specifies that the transmission of the bulk data between system elements on a network is performed by the use of the Xerox Sequenced Packet Protocol (54).

The lower layer protocols that compose the Xerox network structure, such as the Ethernet Specification (16), the Internet Datagram Protocol (54) and the Internet Transport Protocols (54), have only one implementation on each host system. The Xerox Bulk Data Transfer Protocol, however, can be implemented a number of times on a host system. For instance, one bulk data service might support file service applications. Another bulk data service might be implemented in support of print service applications.

Protocol presented mapped out the main structure of this protocol. that being communications among three system elements: the initiator, the Produce remote procedure, and the Consume remote procedure. The initiator receives bulk data requests, and determine the type of transfer needed to accomplish a bulk data transfer. Once this is determined, the Produce and the Consume remote procedures are contacted via Courier remote procedure calls. Arguments are passed to the Produce and the Consume remote procedures that allow them to perform the roles assigned to them by the initiator.

The next chapter uses the general design presented for the Xerox Bulk Data Transfer Protocol to develop a detailed design of this protocol. The detailed design is then used to implement the Xerox Bulk Data Transfer Protocol for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system.

connection established when Produce made the Courier remote procedure call to the Receive remote procedure.

Summary

The emphasis of this chapter is a general design specification of the Xerox Bulk Data Transfer Protocol. A general design of the Xerox Bulk Data Transfer Protocol is presented, because it is the only support protocol for application services on a Xerox Network System that has not been designed or implemented for the VAX 11/780 with the Berkeley Unix 4.2BSD operating system. The general design presented contributes to providing bulk data transfer support that is needed for such application services as electronic filing, printing, and mailing on Xerox Network Systems. These are all the same application services that the Program and Financial Control office would like the VAX 11/780 to also provide on their Xerox Network System.

A brief discussion of the Xerox Courier Protocol is also presented, because it is the basis for communications that is outlined in the Bulk Data Transfer Protocol. The Bulk Data Transfer Protocol uses the remote procedure call feature of the Courier Protocol to assign roles to those system elements that must participate in the transfer of bulk data. The connections established by the Courier remote procedure calls are also used to transport the bulk data between system elements on a network.

The general design of the Xerox Bulk Data Transfer

Immediate Transfer. When Consume is assigned an immediate role, it accepts the bulk data sent to it by the initiator. The bulk data is received by Consumed on the same connection established when the initiator made the Courier remote procedure call to Consume (See Figure IV-8 SADT A32).

Third-Party Transfer. A third-party transfer request requires Consume to communicate directly with the initiator, and indirectly with the Produce remote procedure. The initiator specifies whether Consume is to play an active, or a passive role in a third-party bulk data transfer (See Figure IV-8 SADT A33).

When Consume is assigned an active role in a third-party bulk data transfer, it issues a call to the Send remote procedure located at the same host address as the Produce remote procedure (See Appendix B SADT A3311). Consume then receives the bulk data sent by the Produce remote procedure (See Appendix B SADT A3312). The bulk data is received from the same connection established when Consume made the Courier remote procedure call to the Send remote procedure.

When Consume is assigned a passive role in a third-party bulk data transfer, it waits for a call from the Receive remote procedure that is issued by Produce (See Appendix B SADT A3321). Consume then receives the bulk data sent to it by the Produce remote procedure (See Appendix B SADT A3322). The bulk data is received from the same

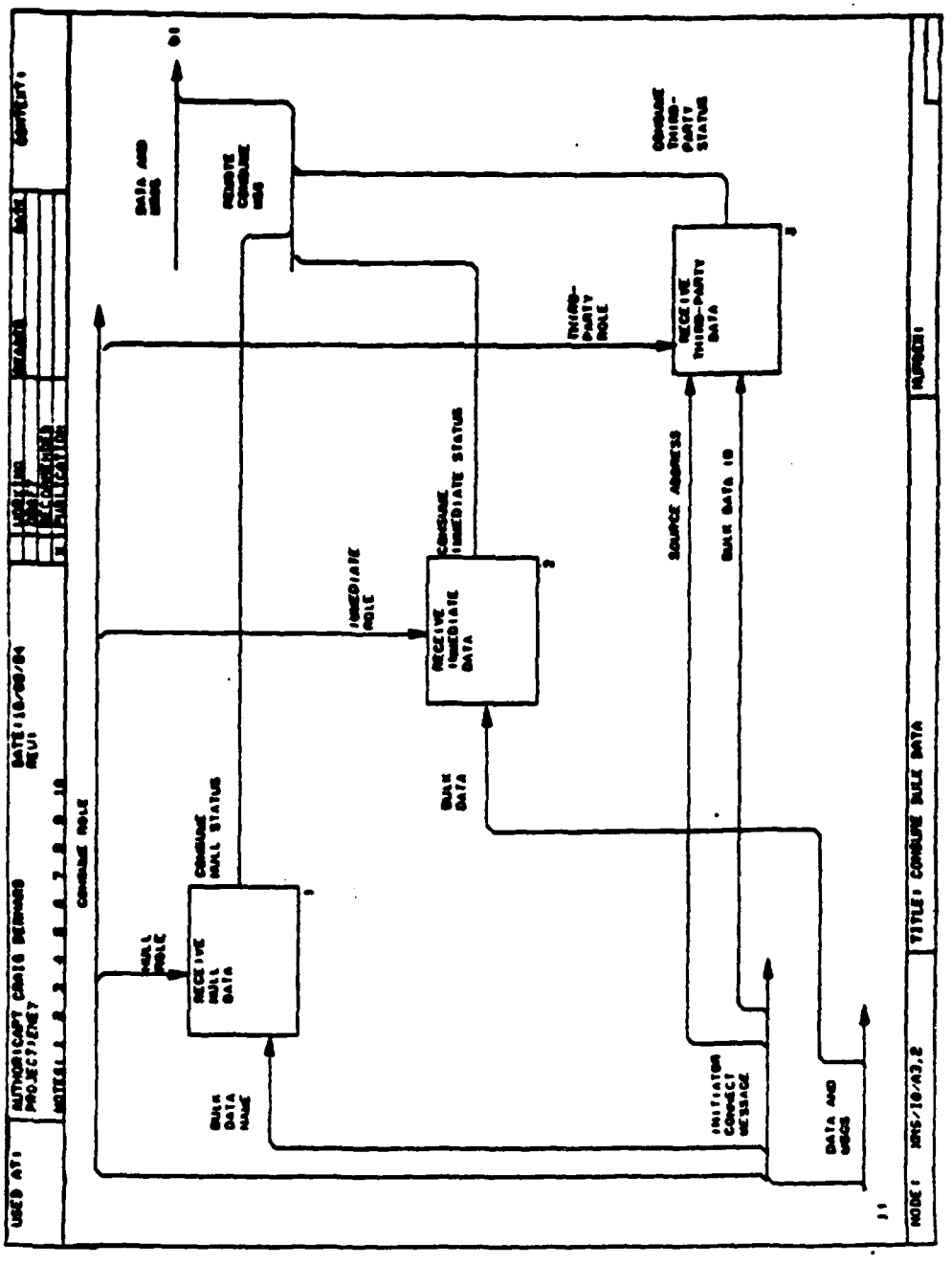


Figure IV-8. SADT A3

When Produce is assigned a passive role in a third-party bulk data transfer, it waits for a call from the Send remote procedure that is issued by Consume (See Appendix B SADT A2421). The bulk data is then sent by Produce to the Consume remote procedure (See Appendix B SADT A2422). The bulk data is sent on the same connection established when Consume made the Courier remote procedure call to the Send remote procedure.

The Consume Remote Produce. The Consume remote procedure, just as the Produce remote procedure, also communicates with two system elements. It communicates directly with the initiator, and indirectly with the Produce remote procedure (See Figure IV-4). The initiator activates the Consume remote procedure supplying arguments. The main argument supplied defines the role Consume is to play in a bulk data transfer (See Figure IV-8 SADT A3). The Consume remote procedure returns the status of performing its assigned role via the initiator Courier connection.

Null Transfer. When Consume is assigned a null role, no bulk data is actually transmitted to Consume (See Figure IV-8 SADT A31). The operation the Consume remote procedure performs, when a null role is assigned by the initiator, is specific to an application service. The Consume remote procedure reports to the initiator whether such an operation is sucessful or is a failure.

Null Transfer. As stated earlier, when Produce is assigned a null role, then no bulk data is actually transferred (See Figure IV-7 SADT A22). The function that the Produce remote procedure performs when a null role is assigned by the initiator is specific to an application service. The Produce remote procedure does report a sucess or failure in performing a null bulk data transfer.

Immediate Transfer. When Produce is assigned an immediate role, the bulk data retrieved at the local Produce host system is sent to the initiator. The bulk data is transmitted to the initiator on the same connection established when the initiator made the Courier remote procedure call to Produce (See Figure IV-7 SADT A23).

Third-Party Transfer. A third-party transfer request requires Produce to communicate directly with the initiator, and indirectly with the Consume remote procedure. The initiator specifies whether Produce is to play an active, or a passive role in a third-party bulk data transfer (See Figure IV-7 SADT A24).

When Produce is assigned an active role in a third-party bulk data transfer, it issues a call to the Receive remote procedure located at the same host address as the Consume remote procedure (See Appendix B SADT A2411). The bulk data is then sent by Produce to a waiting Consume remote procedure (See Appendix B SADT A2412). The bulk data is sent on the same connection established when Produce made the Courier remote procedure call to the Receive remote procedure.

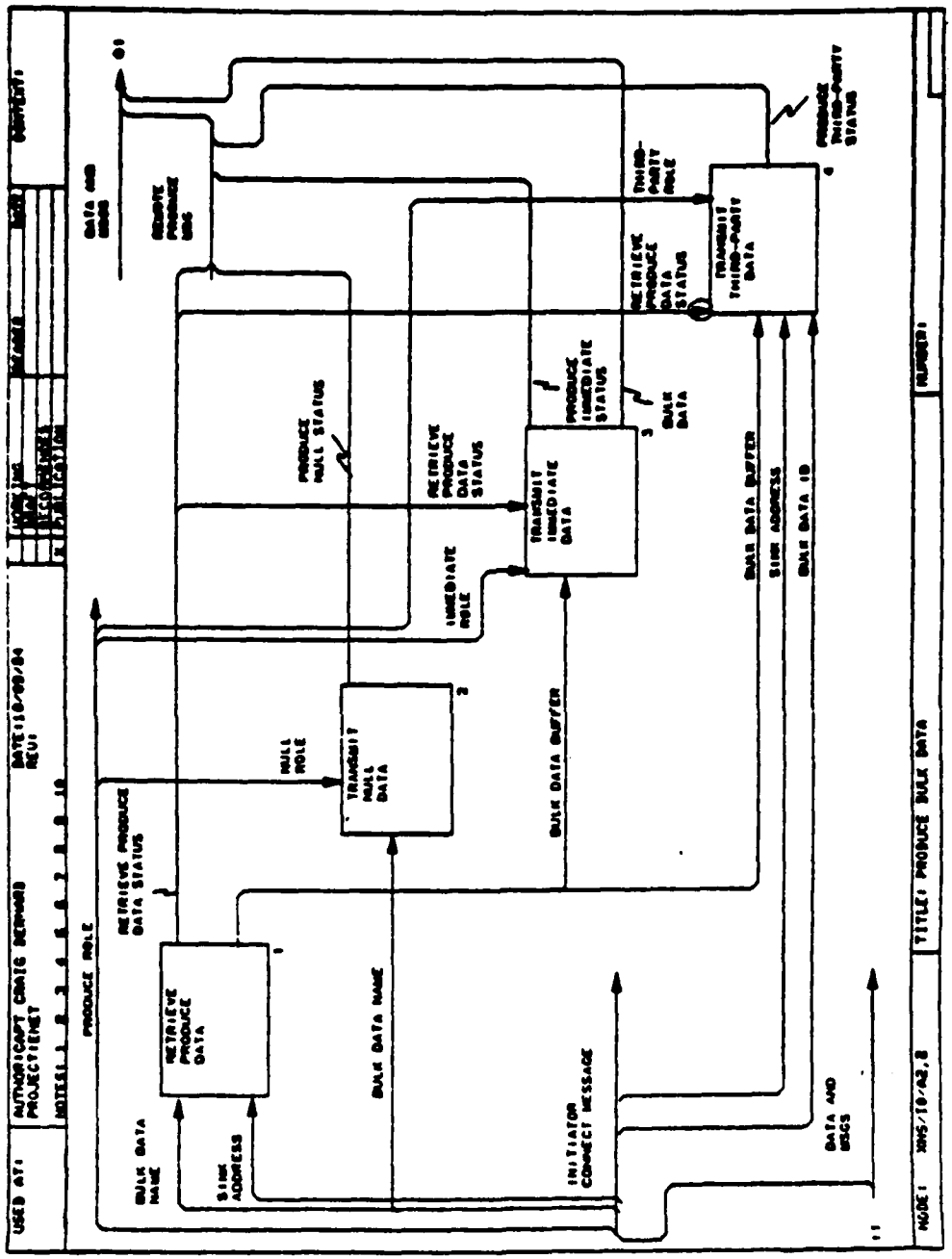


Figure IV-7. SADT A2

that the Produce and the Consume remote procedures understand, the ProduceServer and the ConsumeServer processes call Produce and Consume, respectively, with these arguments (See Figure V-2 and Figure V-3). The status messages the Produce and the Consume remote procedures return after performing a bulk data transfer are encapsulated into Courier data types by the ProduceServer and the ConsumeServer processes. The encapsulated status messages are then sent on the Courier connection by the ProduceServer and the ConsumeServer processes to a waiting initiator system, thereby completing the remote procedure calls to the Produce and the Consume remote procedures.

The top level detailed designs of the Produce and the Consume remote procedures (See Figure V-4 and Figure V-5) are very similar to their top level SADT general designs (See Appendix B, SADT A2 and SADT A3). The differences are that the top level detailed design of Produce has two additional processes that do not appear in its top level SADT general design; and the top level detailed design of Consume has one additional process that does not appear in its top level SADT general design.

The process, called SetRole (See Appendix E-57), is used to decode the role (56:41) the initiator has assigned the Produce remote procedure. This process is also used by the Consume remote procedure for this purpose. This action is represented in the top level SADT general design of the

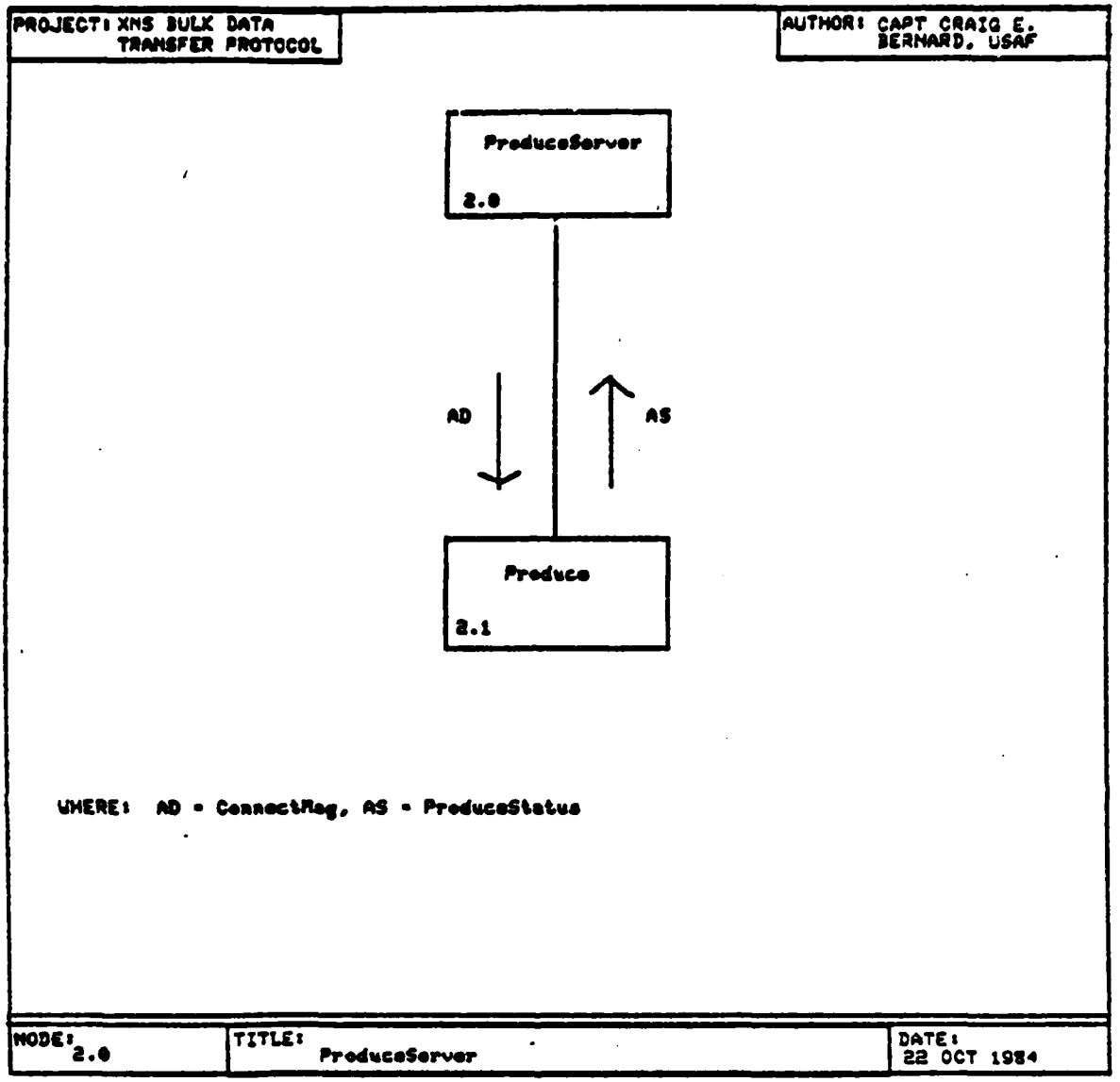


Figure V-2. The ProduceServer Process

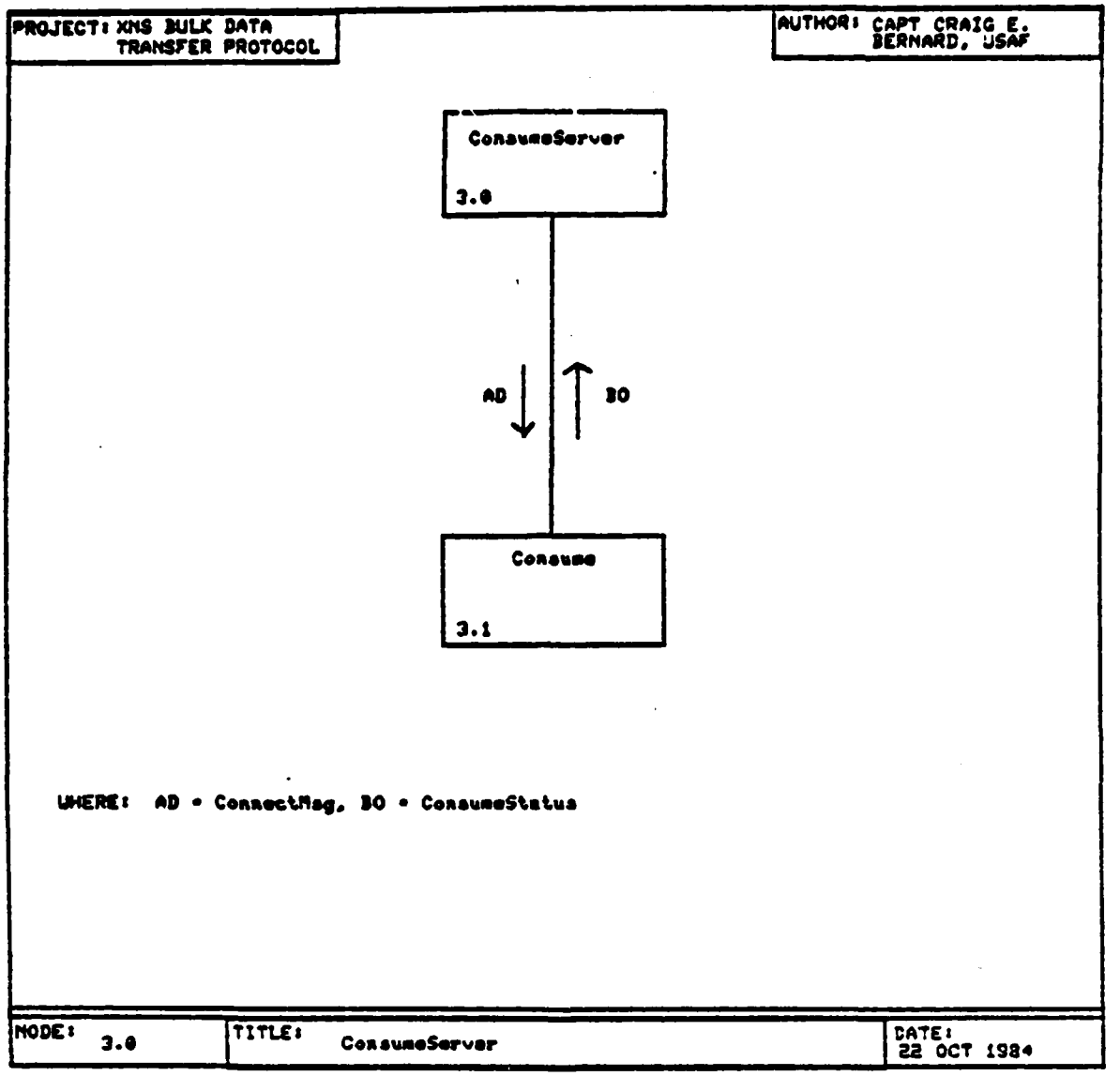


Figure V-3. The ConsumeServer Process

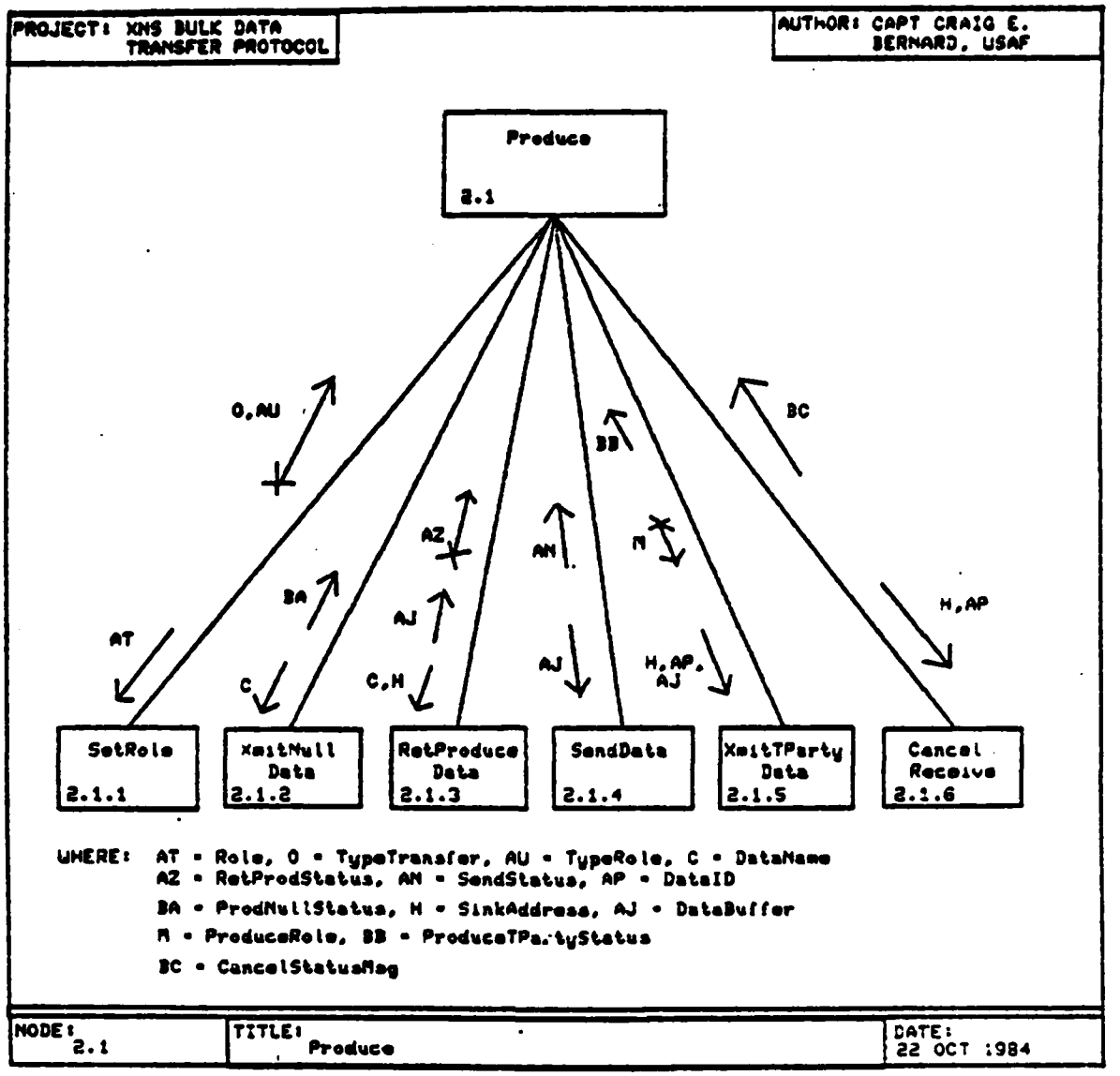


Figure V-4. The Produce Process

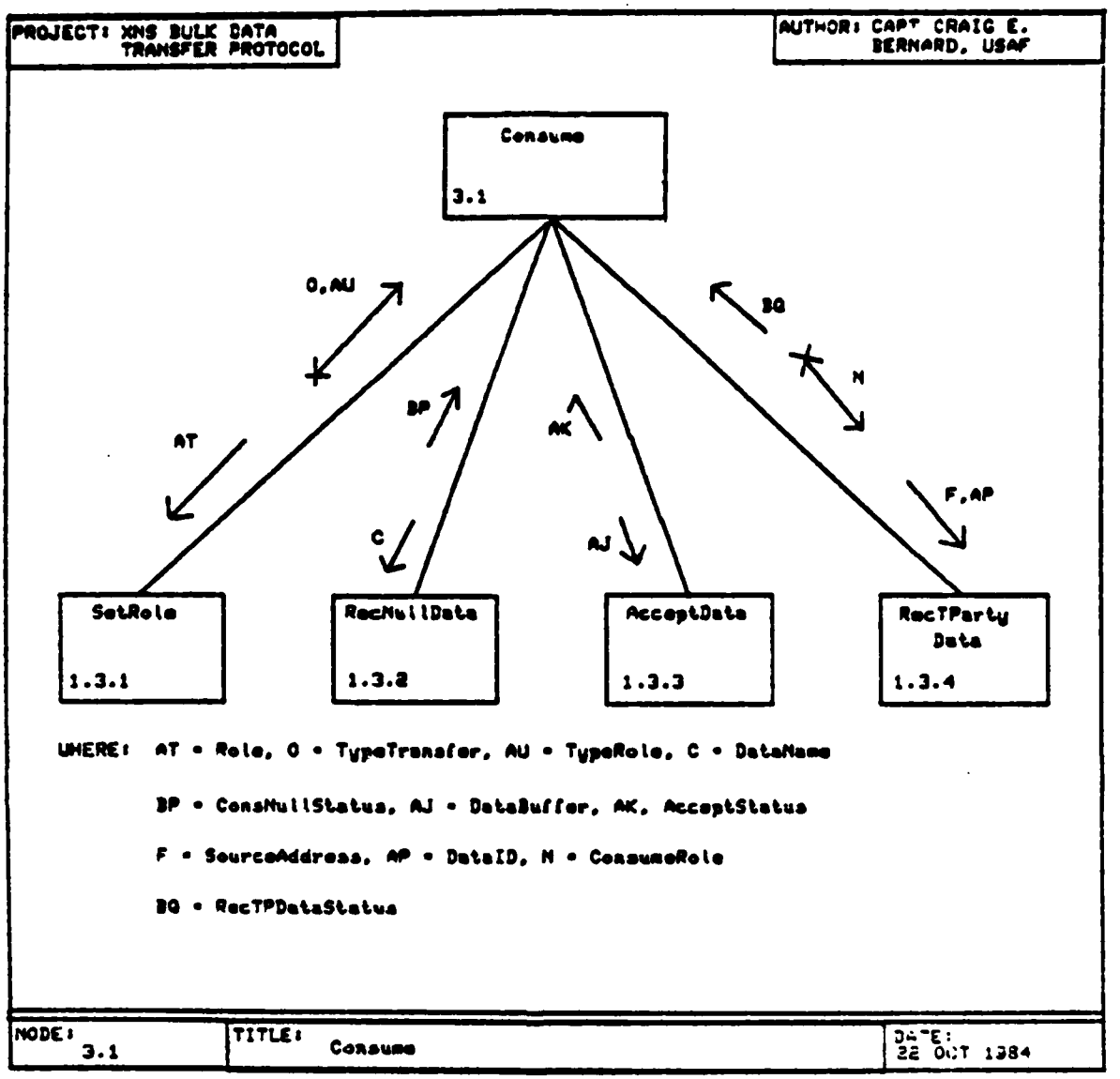


Figure V-5. The Consume Process

Produce remote procedure by the splitting of the Produce Role control variable (See Appendix A2). The same action is represented in the top level SADT general design of the Consume remote procedure by the splitting of the Consume Role control variable (See Appendix A3).

The second process, called CancelReceive (See Appendix E-14), notifies the Consume remote procedure, via the Cancel remote procedure (56:44), that the third-party bulk data could not be sent. This action is not represented in the top level SADT general design of the Produce remote procedure because the notification sent to the Consume remote procedure is optional.

The lower level processes, that complete the detailed design of the Produce and the Consume remote procedures, closely follow the specification of the lower level activities outlined in the SADT general design of Produce and Consume. The lower level detailed design of Produce and Consume, however, specifies in greater detail those processes needed to transfer third-party bulk data. These processes can be identified as processes that allow Produce and Consume to play complimentary active or passive third-party roles.

When the Produce or the Consume remote procedure is assigned an active role in the transfer of third-party bulk data, they use two processes for communicating with the Bulk Data system. One process, called ActTPCommand (See Appendix E-9), is used by the Produce and the Consume remote

procedures to issue calls to the Send, the Receive, and the Cancel remote procedures. Another process, called RecTPStatusMsg (See Appendix E-49), is used by the Produce and the Consume remote procedures to receive return messages from the Send, the Receive, and the Cancel remote procedures. These two processes perform the same functions as the Issue Receive Command activity (See Appendix B, SADT A2411), and the Issue Send Command acitivity (See Appendix B, SADT A3311), that were specified in the SADT general design of the Produce and the Consume remote procedures.

When the Produce or the Consume remote procedure is assigned a passive role in the transfer of third-party bulk data. they use two processes for communicating with the Bulk Data system. These two processes depend on a third process, called GetFileName (See Appendix E-25), for supplying the pathname to a file that the passive Produce or Consume remote procedure uses to communicate with the Bulk Data system.

The first process used for communicating with the Bulk Data system. when the Produce or the Consume remote procedure is assigned a passive role, is called the SetDataAddress process (See Appendix E-56). The SetDataAddress process is used by Produce and Consume for storing the address of a buffer area and the identification (56:43-44) used for a third-party bulk data transfer. The address of a buffer area, and the identification used for a third-party bulk data transfer, are stored in the file

specified by the GetFileName process. In the case of Produce being assigned a passive role, the address of the buffer area is the pointer address to the bulk data that the Send remote procedure is to transmit to an active Consume remote procedure. In the case of Consume being assigned a passive role, the address of the buffer area is the pointer address where the Receive remote procedure is to store the bulk data it receives from an active Produce remote procedure.

The second process used for communicating with the Bulk Data system, when the Produce or the Consume remote procedure is assigned a passive role, is called the MonitorTransfer process (See Appendix E-39). The MonitorTransfer process allows the passive Produce or Consume remote procedure to monitor the transfer of the third-party bulk data. This process performs the same functions as the Wait For Send Command activity (See Appendix B, SADT A2421), and the Wait For Receive Command activity (See Appendix B, SADT A3321), outlined in the SADT general design of the Produce and the Consume remote procedures.

The Bulk Data System. The Bulk Data system is used whenever a third-party transfer is used to transfer bulk data from one host system to another on a network. The Bulk Data system is composed of three remote procedures: Send, Receive, and Cancel. These are the only remote procedures specifically defined by the Xerox Bulk Data

Transfer Protocol (56:43). The Send, the Receive, and the Cancel remote procedures combine to form the Xerox Bulk Data remote program (56:45-46). The Produce and the Consume activates these remote procedures through Courier call messages. Like the Produce and the Consume remote procedures, the Bulk Data system also has a server program for interfacing with Courier call messages.

A detailed design process, called BulkServer (See Appendix E-12), interfaces with the Produce and the Consume remote procedures that issue Courier call messages to the Send, the Receive, and the Cancel remote procedures. The BulkServer decapsulates call messages received from a Courier connection and determines whether the message is for the Send, the Receive, or the Cancel remote procedure. Once this is determined, the appropriate remote procedure is called with the arguments received from the Courier call message (See Figure V-6). After the appropriate remote procedure has finished executing, its results of participating in a third-party transfer are encapsulated into Courier data types by the BulkServer process. The BulkServer process then sends the encapsulated results to the Produce or the Consume remote procedure that issued the Courier call message.

The top level detailed designs of the Send (See Figure V-7), the Receive (See Figure V-8), and the Cancel (See Figure V-9) remote procedures do not have SADT general

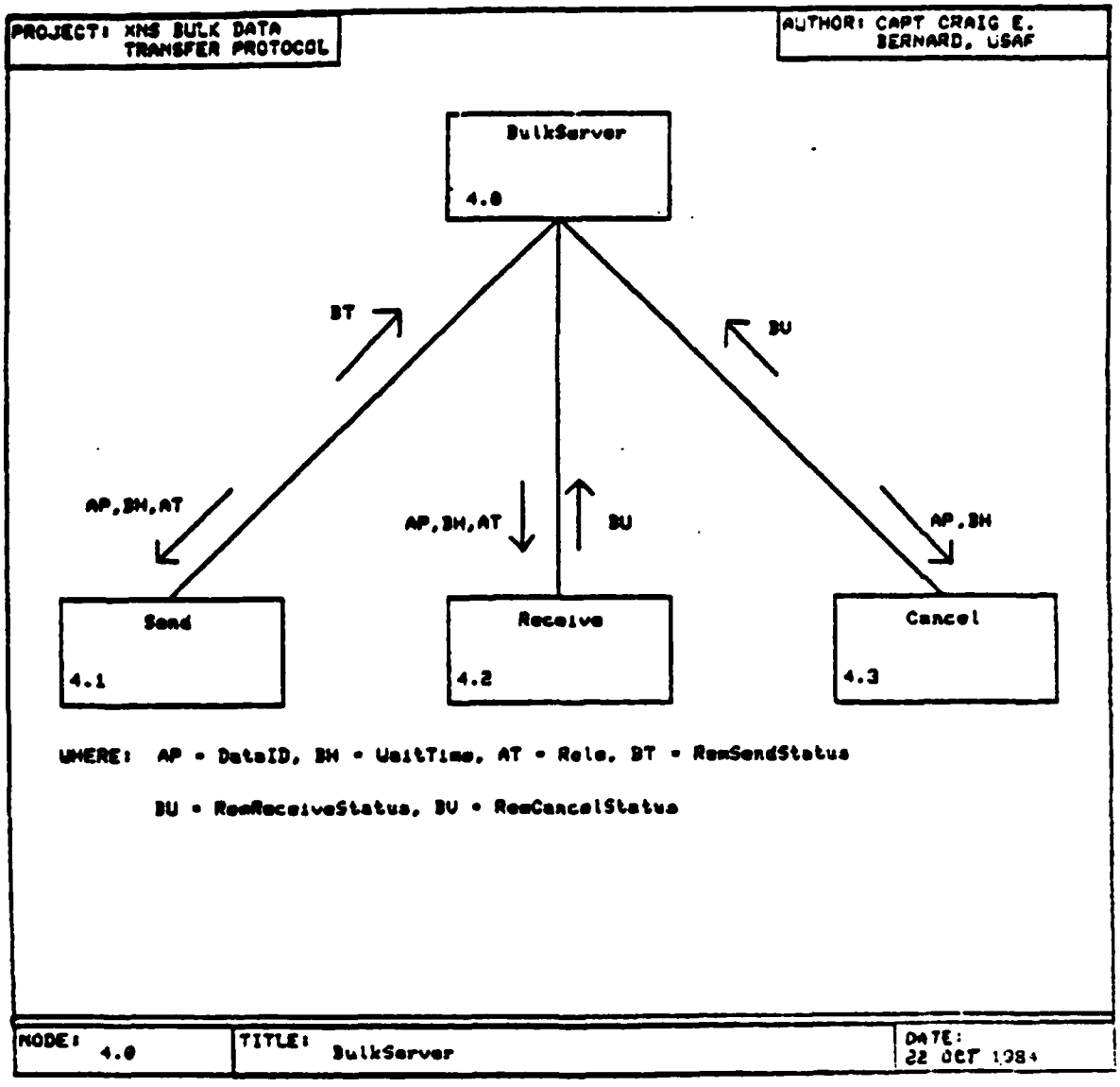


Figure V-6. The BulkServer Process

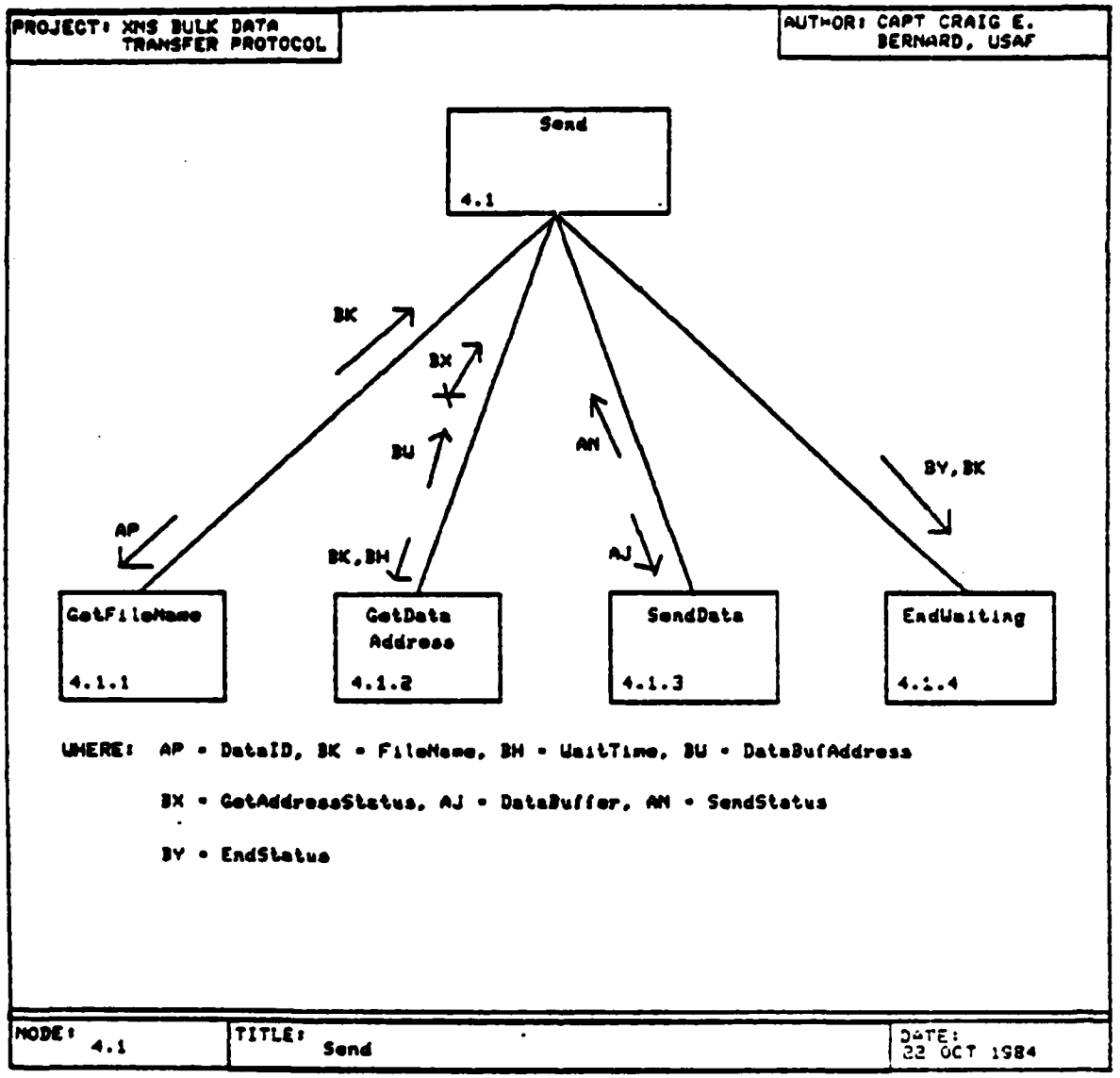


Figure V-7. The Send Process

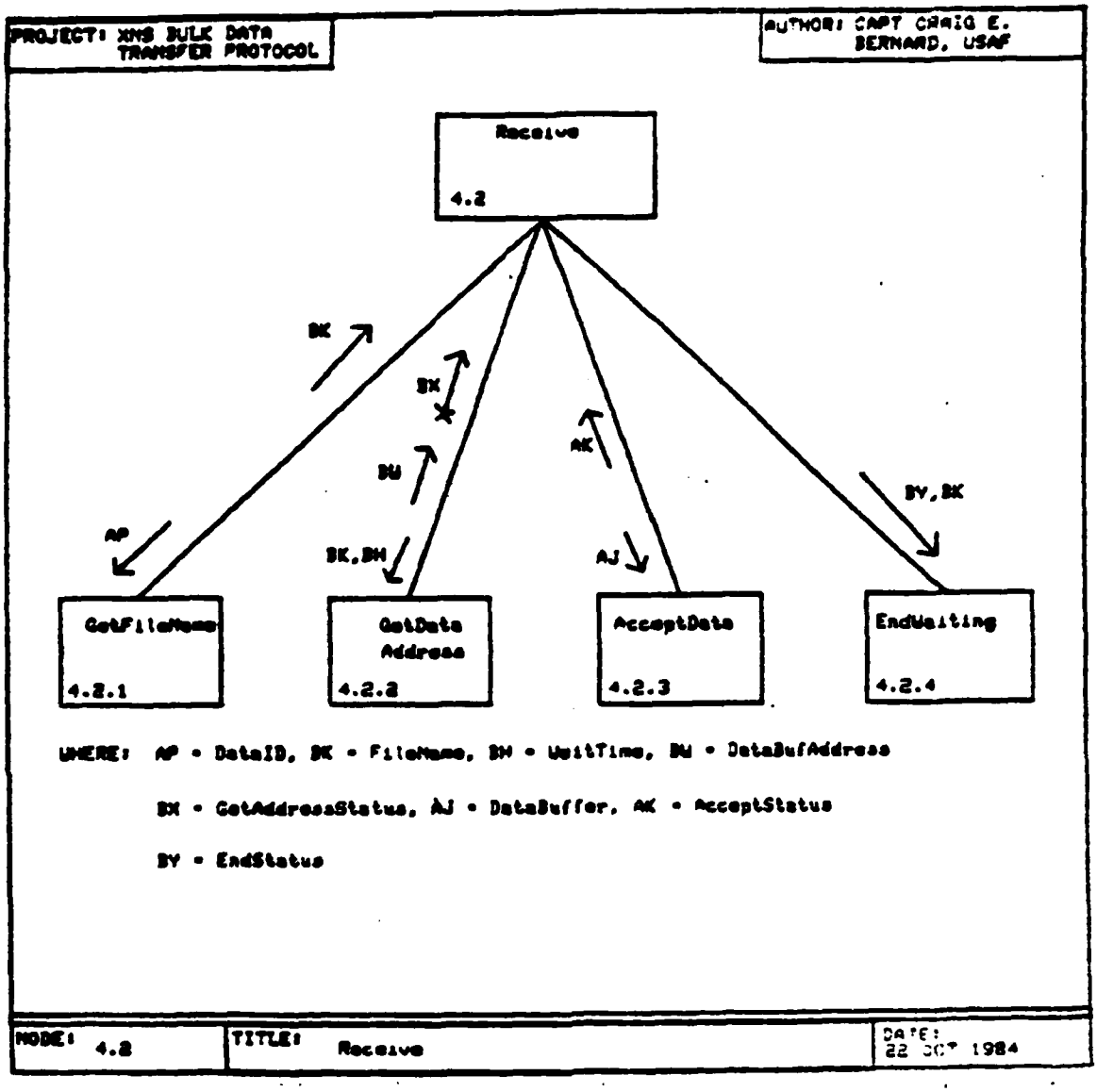


Figure V-8. The Receive Process

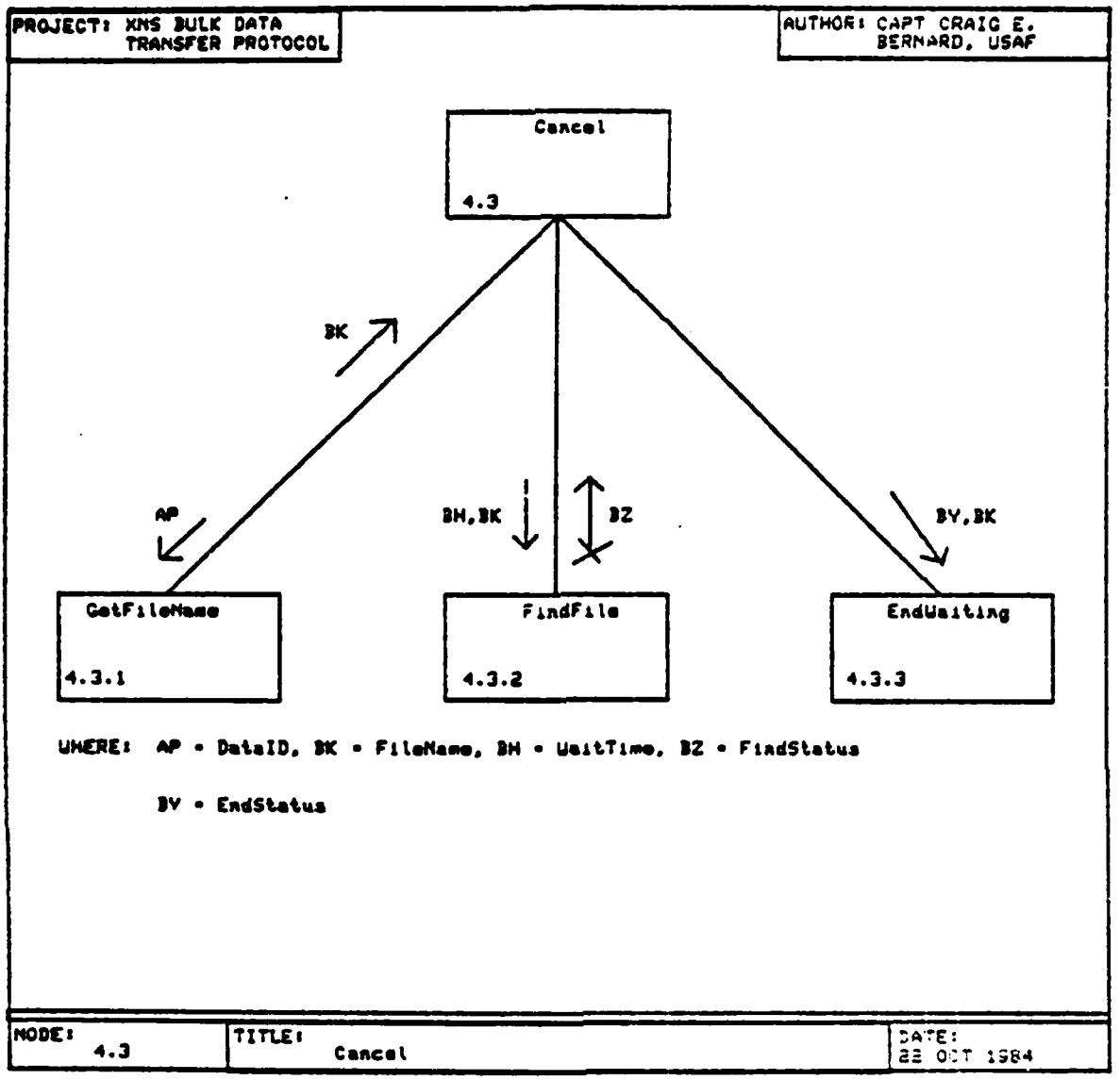


Figure V-9. The Cancel Process

design specifications. The reason for this is that the emphasis of the SADT general design is on the main structure of the Xerox Bulk Data Transfer Protocol, that being the communications among the initiator, the Produce remote procedure, and the Consume remote procedure. The SADT general design does show the role the Bulk Data system plays in the transfer of bulk data (See Appendix B, SADT A2411, and A3311).

The Send Remote Procedure. The Consume remote procedure activates the Send remote procedure when it is assigned an active role in a third-party bulk data transfer. The Consume remote procedure activates the Send remote procedure that is located at the same host address as the Produce remote procedure that is playing a complimentary passive role in a third-party bulk data transfer. The Consume remote procedure then waits for the Send remote procedure to send Produce's bulk data. The Send remote procedure sends Produce's bulk data on the same connection that was established when Consume issued the Courier call message to Send.

The Send remote procedure uses four detailed design processes to accomplish the transfer of Produce's bulk data to a waiting Consume remote procedure. The first detailed design process, called GetFileName, supplies the name of the file that Send and Produce use to communicate the transfer of Produce's bulk data. The second detail process, called GetDataAddress (See Appendix E-24), returns the pointer

Xerox office automation equipment and mainframe computers, such as the VAX 11/780, is highly dependent on Xerox to release its application services protocols for public use. Xerox has just recently released its electronic printing protocols for public use. They are also planning to release the electronic filing protocols for public use once they feel it has evolved to a stable standard. Hence, the future looks bright for a full interface between the VAX 11/780 and Xerox office automation equipment at the application services level.

Recommendations

This investigation is an initial effort that not only assists the Program and Financial Control office in satisfying their requirements for interfacing the VAX 11/780 with their Ethernet based XNS system, but also provides a basis for future thesis work. The Program and Financial Control office was not the only entity interested in this effort. The people at the Xerox Palo Alto Research Center and at Advanced Computer Communications were also interested in this effort. The Program and Financial Control office, as well as the people at the Xerox Palo Alto Research Center and at Advanced Computer Communications, are also interested in continued research in the area of interfacing the VAX 11/780 and Ethernet based Xerox Network Systems. Therefore, the following specific recommendations are provided:

ACC.

D. An interpretor should be available by the time this report is released that will provide an interface between the Xerox file service protocol, and the ACC file service protocol.

The Program and Financial Control office, being part of the Department of Defense, is mandated to use the DARPA TCP/IP protocols for internetworking. Therefore, the implementation of TCP/IP on the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, was also investigated. It was learned that the Berkeley Unix 4.2BSD operating system provides full support for the DARPA TCP/IP protocols. It was also learned that the Berkeley Unix 4.2BSD operating system also fully supports the DARPA application services FTP, SMTP, and TELNET.

This investigation learned that most of the lower level support protocols used by XNS application services have already been designed and implemented for the Vax 11/780 using Berkeley Unix 4.2BSD. However, there are still some key support protocols that have not been fully implemented for the VAX 11/780, such as the Xerox Bulk Data Transfer Protocol and the Clearinghouse Protocol.

The Ethernet based Xerox Network System is one of the most widely used local area network today. The development of interfaces at the application services level, between

should be available for Berkeley Unix 4.2BSD by the time this report is released.

4. XNS level three (the Courier Protocol and the Xerox Bulk Data Transfer Protocol)
   A. The Courier Protocol is fully implemented by ACC, and it should be available for Berkeley Unix 4.2BSD by the time this report is released.
   B. A general design, detailed design, code implementation, and testing of the Xerox Bulk Data Protocol is presented in chapters four and five.
   C. The Courier Protocol is fully implemented by Berkeley Unix 4.2BSD, however this implementation is not supported by XNS levels' one and two at present.

5. XNS level four (Application services)
   A. The Xerox electronic filing and mailing protocols have not been released for public use.
   B. The Xerox electronic printing protocol has just recently been released for public use.
   C. The Clearinghouse distributed database protocol has been partially implemented by

but no device driver software is available for Berkeley Unix 4.2BSD.

C. Device driver software is available for the Interlan and 3Com Ethernet controller boards as part of Berkeley Unix 4.2BSD.

D. Fully implemented by Advanced Computer Communications (ACC), and it should be available for Berkeley Unix 4.2BSD by the time this report is released.

2. XNS level one (Internet Datagram Protocol)

A. Fully implemented by NRC and Bridge Communications, including a Berkeley Unix 4.2BSD version.

B. Fully implemented by Interlan, but does not have a Berkeley Unix 4.2BSD version.

C. Fully implemented by ACC, and it should be available for Berkeley Unix 4.2BSD by the time this report is released.

3. XNS level two (Internet Transport Protocols)

A. Fully implemented by NRC and Bridge Communications, including a Berkeley Unix 4.2BSD version.

B. Fully implemented by Interlan, but does not have a Berkeley Unix 4.2BSD version.

C. Partially implemented by ACC, and it

Conclusions and Recommendations

Conclusions

This investigation was initiated because the Program and Financial Control office needed to interface the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, and their Ethernet based Xerox Network System. This interfacing would allow such services as electronic filing, printing, and mailing between the VAX 11/780 and Xerox computer devices on an Ethernet. However, since Xerox computer devices on an Ethernet use the layered Xerox network structure for communications, this same structure would also have to exist on the VAX 11/780. Therefore, this investigation concentrated on determining which of the protocols, that compose the five level Xerox network structure, needed to be implemented for the VAX 11/780.

At the time this report was concluded, the status of the Xerox protocols available and implemented for the VAX 11/780, using the Berkeley Unix 4.2BSD, is as follows:

1. XNS level zero (Ethernet Specification)
   A. Fully implemented by Bridge Communications and Network Research Corporation (NRC), including device driver software for Berkeley Unix 4.2BSD.
   B. Fully implemented by Interlan and 3Com,

"C" programming language for implementation of all network functions. The Vax 11/80 with the Berkeley 4.2BSD operating system is the host system the Program and Financial Control office wants to interface with their Ethernet based XNS system. The "C" programming language is also used because the interfaces to the Courier Protocol and the Sequenced Packet Protocol are in the "C" language.

The dynamic testing of the code implementation could not be performed for a number of reasons. One reason is that the Berkeley 4.2BSD operating system could not be acquired in time for this research. Another reason is the Courier Protocol and the Sequenced Packet Protocol, the protocols the code implementation depends on, are currently not implemented for the Berkeley 4.2BSD operating system.

However, static analysis is performed and dynamic analysis is outlined for the code implementation. Static analysis is used to ensure the syntactic and semantic correctness of the code implementation. The dynamic analysis test procedures outlined for the code implementation specifiy those conditions that should be tested for the initiator system, the Produce remote system, the Consume remote system, and the Bulk Data system.

system. The code implementation of the Xerox Bulk Data Transfer Protocol is a model for implementing a bulk data services on a network system. The test plan of the four systems addresses those conditions which should be tested for in a particular code implementation of the Xerox Bulk Data Transfer Protocol for a given application service.

Summary

This chapter presented an implementation and testing of the Xerox Bulk Data Transfer Protocol. The implementation is based on the general design of the Xerox Bulk Data Transfer Protocol outlined in chapter four. The implementation is composed of two parts. The first part is a detailed design of the SADT general design. The second part is the derivation of code in a high level programming language from the detailed design.

The detailed design of the SADT general design is presented using the structure chart technique. The detailed design is composed of four systems, the initiator system, the Produce remote procedure system, the Consume remote procedure system, and the Bulk Data system. These systems represent the entities that negotiates the transfer of bulk data from one host system to another.

The code implementation of the detailed design is in the "C" high level programming language. This is done for a number of reasons. The main reason being that the Vax 11/780 with the Berkeley 4.2BSD operating system uses the

The test plan is composed of four system test; a test of the initiator system, a test of the Produce remote system, a test of the Consume remote system, and a test of the Bulk Data system (See Appendix F). A separate test is outlined for each of the four systems because it is possible for a host system not to have all four systems, therefore only the systems that a host system has needs to be tested. For instance, a host system might only produce bulk data. Therefore, it only has to test its Produce remote system and its Bulk Data system.

The test plan uses the equivalence partitioning technique for performing dynamic analysis. The equivalence partitioning technique is used because it selects a reasonably small subset of test cases, out of the infinitely large set of possible test cases that has a high probability of finding errors (37). Given some input to a system, valid and invalid statements about the input can be listed (See Appendix F-2). Each valid and invalid statement is then given a unique number. Test cases, which are specified values for the inputs to a system, are then constructed to cover as many valid and invalid statements about the inputs to a system.

The test plan presented for the code implemenation of the Xerox Bulk Data Transfer Protocol only lists the input conditions, the valid equivalence classes, and the invalid equivalence classes. It does not list any test cases. Recall, test cases are specified values for inputs to a

White box analysis involved evaluating the code in each module. One area evaluated was to ensure that variable references were of the same data type. Another area evaluated was to ensure that variables had been assigned values before they were referenced. Finally, path analysis was used to ensure each line of code in a module could be executed.

Interface analysis involved evaluating subroutine calls between modules. The arguments passed between modules were checked to ensure they were in the correct calling sequence. The data types of the arguments passed between modules were checked to ensure they were of the same data type. Modules that passed values to submodules through arguments were checked to ensure those arguments were assigned values. Finally. submodules that were supposed to return values through arguments were checked to ensure that those arguments were assigned values.

Dynamic Analysis. Dynamic analysis involves the execution of a program over sample test data followed by analysis of the output (28:185). This type of analysis is sometimes referred to as black box testing, because during testing you are only concerned with the inputs and the outputs of a module, or a system. Dynamic analysis could not be performed, because the code implementation was not installed on a host system. However, a test plan is outlined for dynamic analysis of the Xerox Bulk Data Transfer Protocol.

Testing

The code implementation of the Xerox Bulk Data Transfer Protocol designed for the Vax 11/780 with the Berkeley 4.2BSD operating system was not installed and tested on this host system. There are a number of reasons why the code implementation was not installed and tested. First, the Berkeley 4.2BSD operating system could not be acquired in time for this research. Second, at the time of this report the ACC NU-11/XNS software package was not implemented for the Vax 11/780 with the Berkeley 4.2BSD operating system. Third, the Vax 11/780 used in this research has not been configured with an Ethernet controller board. Finally, an Ethernet based XNS system could not be acquired in time for testing. Therefore, test procedures are used to perform static analysis on the code implementation of the Xerox Bulk Data Transfer Protocol. Test procedures are also outlined for performing dynamic analysis once the code implementation has been installed on the Vax 11/780 with the Berkeley 4.2BSD operating system, along with the ACC NU-11/XNS software package, and an Ethernet controller board.

Static Analysis. Static analysis of a software system involves the use of validation methods that do not require the actual execution of the system (28:83). Static analysis was used to ensure the syntactic and semantic correctness of the code implementation of the Xerox Bulk Data Transfer Protocol. This was done by performing two types of analyses on the code implementation, white box analysis, and interface analysis.

4.2BSD operating system, it should be available for this host system configuration by the time this report is released.

The host system that the coding implementation of the Xerox Bulk Data Transfer Protocol is designed for is the Vax 11/780 with the Berkeley 4.2BSD operating system. This host system is used because the aim of this thesis investigation is to assist the Program and Financial Control office in networking their XNS environment and the Vax 11/780 with the Berkeley Unix 4.2BSD operating system.

The high level programming language used to implement the detailed design of the Xerox Bulk Data Transfer Protocol is the "C" programming language (29, 30, 32). The "C" programming language is used, because the Berkeley Unix 4.2BSD operating system uses it for most of its system programming and networking applications. The "C" programming language is also used, because the NU-11/XNS user interfaces to the Courier Protocol and the Xerox Sequenced Packet Protocol, are only in the "C" programming language.

The coding implementation of the Xerox Bulk Data Transfer Protocol detailed design is a one-to-one transformation of the detailed design processes to "C" programming modules (See Appendix H). Some of these modules rely on system routines that are not a part of the "C" programming language, but are supplied by the operating system. Any system routines used are documented in the module header located before the code of each module.

exist. The third detailed design process, calledEndWaiting, signals to the passive party that the bulk data transfer could not be attempted.

Code Implementation. The detailed design of the Xerox Bulk Data Transfer Protocol is used to implement this protocol in a high level programming language on a host system. Any implementation of the Xerox Bulk Data Transfer Protocol must use the specified support protocols of the XNS structure, if it is to be in accordance with the outlined standard. The Xerox Bulk Data Transfer Protocol outlines communications among the initiator, the Produce remote procedure, and the Consume remote procedure via the remote procedure call facility of the Courier Protocol. It also specifies that the bulk data is transmitted between host systems through the use of the Xerox Sequenced Packet Protocol.

The Advance Computer Communications' XNS Protocol Package, called NU-11/XNS-Version 2.0 (43), is used to support the coding implementation of the Xerox Bulk Data Transfer Protocol. The NU-11/XNS software is used because currently it is the only software package that has an implementation of the Courier Protocol (41). The NU-11/XNS software package also contains support for the Xerox Sequenced Packet Protocol (42), along with other protocols that compose the XNS architecture structure (43). Although at the time of this research, the NU-11/XNS-Version 2.0 is not implemented for the Vax 11/780 with the Berkeley Unix

transfer of Produce's bulk data. The second detail process, called GetDataAddress, returns the pointer address to a buffer area specified by Consume. This Receive remote procedure uses this buffer area to store the bulk data it receives from the Produce remote procedure. The third detail process, called AcceptData, receives the bulk data sent by the Produce remote procedure. The fourth detailed design process, called EndWaiting, signals to Consume that the bulk data transfer is completed.

The Cancel Remote Procedure. The active party in a third-party transfer uses the Cancel remote procedure to signal to the passive party that the bulk data transfer could not be attempted. The Cancel remote procedure provides a means to prevent the passive party from idly waiting for a bulk data transfer that cannot happen. The Produce remote procedure might call Cancel when it cannot locate the requested bulk data. The Consume remote procedure might call Cancel when it cannot receive the bulk data Produce is to send.

The Cancel remote procedure uses three detailed design processes to perform the task of notifying the passive party that a bulk data transfer cannot be attempted. The first detailed design process, called GetFileName, supplies the name of the file that the passive party uses to monitor the transfer of the bulk data. The second detailed design process, called FindFile (See Appendix E-22), ensures that the file the passive party is supposed to be monitoring,

address to Produce's bulk data. The third detail process, called SendData, transmits Produce's bulk data to the waiting Consume remote procedure. The fourth detailed design process, called EndWaiting (See Appendix E-19), signals to Produce that the bulk data transfer is completed.

The Receive Remote Procedure. The Produce remote procedure activates the Receive remote procedure when it is assigned an active role in a third-party bulk data transfer. The Produce remote procedure activates the Receive remote procedure that is located at the same host address as the Consume remote procedure that is playing a complimentary passive role in a third-party bulk data transfer. The Recieve remote procedure accepts the bulk data sent by the Produce remote procedure on behalf of the passive Consume remote procedure. The Receive remote procedure then waits for the Produce remote procedure to send its bulk data. The Produce remote procedure sends its bulk data on the same connection that was established when Produce issued the Courier call message to Receive. The Receive remote procedure accepts the bulk data sent by the Produce remote procedure on behalf of the passive Consume remote procedure.

The Receive remote procedure uses four detailed design processes to accomplish the reception of Produce's bulk data on behalf of a Consume remote procedure. The first detailed design process, called GetFileName, supplies the name of the file that Receive and Consume use to communicate the

1. An Ethernet network should be established at AFIT. The hardware is already there for connecting the AFIT research VAX 11/780 to an Ethernet. In fact, AFIT already has an Ethernet controller for the VAX 11/780, an Ethernet Transceiver, an Ethernet Transceiver cable, and Ethernet coaxial cable available for constructing an Ethernet local area network.

2. The Program and Financial Control office should be contacted in an effort to acquire one of their Ethernet networks for hardware support in the research of interfacing the VAX 11/780 with Xerox office automation equipment on an Ethernet.

3. The Advanced Research Corporation has expressed an interest in allowing AFIT to become a beta test site for their XNS products. Therefore, a follow-up should be made in this area.

4. The Xerox Palo Alto Research group has setup joint research efforts with many institutions. An effort should be made to include AFIT has one of those institutions that does joint research with Xerox.

5. A direct follow-on thesis to this thesis effort

could deal with the installation and thorough dynamic testing of the design and implementation of the Xerox Bulk Data Transfer Protocol presented in chapters four and five. This new thesis effort would however depend on the acquiring of ACC XNS software, which might be possible if AFIT becomes a beta test site for their XNS products. This new thesis effort would also require the installation of an Ethernet controller board into the bus of the VAX 11/780, along with the construction of an Ethernet local area network for testing.

6. Another interesting area, which is also of interest to the Program and Financial Control office, is the development of a protocol converter between the DARPA TCP/IP protocols, and the XNS Internet Datagram and Internet Transport Protocols.

7. Continuing the effort of providing electronic filing, printing, and mailing services between the Xerox office automation computers and the VAX 11/780.

8. Even if an Ethernet based Xerox Network System cannot be established at AFIT, research should still be pursued in the use of applying some of the Xerox protocols to new network systems being

developed, as well as for existing network systems.

9. Once an Ethernet network system as been established at AFIT, the interfacing of it with other networks at AFIT, such as DELNET (26, 45), should be initiated.

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The Program and Financial Control ("P&FC") office would like to be able to perform electronic filing, mailing, and printing services between the VAX 11/780, using the Berkeley Unix 4.2BSD operating system, and Ethernet based Xerox Network Systems (XNS). This study researched the implementation of an electronic filing service between the VAX 11/780 and Ethernet based XNS systems. This study also researched implementations of the DARPA TCP/IP protocols on the VAX 11/780, because P&FC is mandated by DOD to use these protocols for internetworking systems.

This study began by outlining the protocol specifications required for interfacing with XNS systems. An extensive literature search was then performed to determine which of the XNS protocol specifications, as well as the TCP/IP protocols, were already implemented for the VAX 11/780. It was found that Berkeley Unix 4.2BSD contains an implementation of TCP/IP. It was also found that the Xerox Bulk Data Transfer Protocol, a protocol used by the electronic filing service to transfer files, was not implemented. Therefore, a design, implementation, and testing of the Bulk Data Transfer Protocol were presented. With the design and implementation presented, most of the protocols needed to implement an electronic filing service on the VAX 11/780 exist. However, Xerox has not yet released its electronic filing protocol for public use.

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